WILDLIFE TOXICOLOGY FUND

THIRD ANNUAL REPORT TO THE MINISTER OF THE ENVIRONMENT

Environment Canada Environnement
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WILDLIFE TOXICOLOGY FUND 1987 - 1988

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TO THE MINISTER OF THE ENVIRONMENT

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WILDLIFE TOXICOLOGY FUND 1987 - 1988

THIRD ANNUAL REPORT TO THE MINISTER OF THE ENVIRONMENT

Summary

The Wildlife Toxicology Fund (WTF) has completed its first three years of operation with a solid and impressive record of achievement. Over the three years, 96 proposals have been received. Fifty-three were approved for funding from 24 institutions in eight provinces, with two projects being conducted in the Canadian Arctic. In dollar terms, Environment Canada has obtained $5.9 million in priority wildlife toxicology research for an investment of $2.3 million. Administrative costs have been paid by a donation to World Wildlife Fund from Noranda Inc.

Research funded by the WTF has addressed priority wildlife toxicology concerns for many Canadian ecosystems. These include: the effects of Great Lakes contamination on wildlife; the impact of acid rain on wildlife; and the effect of pesticides on the aquatic and terrestrial life of the prairies. As the results from these projects are received, they are channelled to those decision-makers who are in the best position to act on them.

The WTF has now reached the end of its initial three-year mandate. Due to the success of the grant program, Environment Canada and World Wildlife Fund have agreed to renew the WTF for a second three-year period. In order to broaden the program's funding base, Environment Canada is contributing $1 million over three years and WWF has made a commitment to raise at least $200,000 in each of the next three years. Contributions for the renewed WTF have already been received from the Ontario Ministry of the Environment, the Quebec Ministry of the Environment, Alcan Aluminum Ltd., and Fisheries and Oceans Canada.

Brief History

The WTF was established through a Memorandum of Understanding on June 4, 1985 between Environment Canada and World Wildlife Fund. The purpose of the program is "to provide high quality scientific information that can be directly applied to the protection of wildlife in Canada from irreversible harm caused by toxic chemicals in the environment." In addition, the WTF is intended "to enhance and develop private sector expertise, and to act as a stimulus for the joint funding of research projects."

During the first three years of the WTF, the selection criteria called for proposals advocating practical, applied research of a high scientific quality and providing information useful in addressing areas identified by the Department of the Environment as reflected in the following priority concerns:

1. Effects of agricultural and/or forestry chemicals on wildlife.

2. Effects of toxic industrial pollutants on wildlife.

3. Monitoring the success of measures taken to mitigate the effects mentioned in 1 and 2.

4. Developing and implementing techniques that use wildlife as indicators of toxic chemicals in the environment.

5. Examining environmental pathways by which toxic substances may affect wildlife.

To meet its objective of catalyzing funds from other sources, the WTF will only fund research proposals to a maximum of 50 percent of the cost of the project.

On this basis Environment Canada committed $1 million per year over three years. WWF Canada agreed to administer the program by appointing jointly with Environment Canada a Research Advisory Board to receive and evaluate all proposals; by providing all application forms, brochures, announcements, etc.; and by monitoring project progress and results in close co-operation with Environment Canada. Noranda Inc. has provided corporate donations totalling $140,000 over the three-year period to cover WWF's costs associated with administering the Wildlife Toxicology Fund. Additional funding for administrative costs has been received from ESSO Resources Canada Ltd., Polysar Ltd., and Inco Ltd.

Overview of WTF Activities 1985 - 1988

The Research Advisory Board of the Wildlife Toxicology has guided the program's grant-making since its outset. The group represents some of the best and most independent scientific expertise in wildlife toxicology in Canada. Environment Canada is represented on the Board by two Board members. With Dr. Donald Chant as Chairman, the Board met three times during the three-year period.

Bilingual information materials were prepared at the beginning of the first year of the WTF and circulated to approximately 2,000

individual researchers and agencies known to be interested in wildlife toxicology in Canada. WWF's staff visited a number of Canadian universities to discuss the Fund with their research officers, articles were drafted and placed in Canadian university publications, advertisements were paid for in relevant scientific journals, and a number of articles appeared in various professional or industry publications, as well as in the popular press.

Over the three-year period, a number of press releases have been issued jointly by Environment Canada and WWF regarding specific research projects approved for funding. WWF worked closely with the Environment Canada Information Directorate on these. The work of the WTF has also been featured prominently in WWF Canada's annual reports and regular newsletters.

During the three years of operation, 97 proposals have been received, and 44 refused. Fifty-three proposals were approved for funding from 24 institutions in eight provinces, with two projects being conducted in the Arctic. (A summary of the projects is contained in Appendix A and a detailed description of each project is contained in Appendix D.) In dollar terms, Environment Canada has obtained $5.9 million in high quality wildlife toxicology research for an investment of $2.3 million.

The Third Year

During 1987/1988, the Wildlife Toxicology Fund received 23 new project applications. Of the total, 13 proposals were refused and 10 proposals were approved for funding. WTF funding for these new projects totalled $271,880 which catalyzed an additional $480,043 in funding from other sources.

As in the two previous years, all projects recommended for funding were forwarded with a standard form signed by the Chairman and Executive Co-ordinator for approval and issuing of a cheque by Environment Canada. In this regard, the Board would like to offer its gratitude for the prompt and efficient co-operation of Douglas K. Pollock, Director of Management and Administration at the Canadian Wildlife Service.

Total funds granted by the WTF in 1987/1988 were $903,953. This figure includes the annual installments for projects approved in the previous two years. Matching funds for these projects totalled $1.2 million. Therefore, in the third year of operation, Environment Canada gleaned $2.3 million in toxicology research of the highest calibre.

Research Results To Date

The scientific quality and significance of the work supported by the Wildlife Toxicology Fund has been of a uniformly high quality throughout the three-year period. Moreover, the research continues to address the critical wildlife toxicology issues confronting the country and provide advances in our basic understanding of how and why toxic chemicals affect wildlife species in a wide range of ecosystems. Such understanding contributes significantly to effective control of harmful chemicals.

Great Lakes Contamination: A number of WTF projects are examining the effects of toxic chemicals in the Great Lakes, including dioxin in Herring Gulls and the now "famous" Sarnia blob.

At the University of Windsor, the utility of a variety of wildlife species (mostly invertebrates) as biomonitors of hydrocarbon pollution are being assessed. Included among the preliminary findings is evidence that spottail shiners, bluntnose minnows and brook silversides rapidly accumulate significant amounts of toxic compounds and show significant differences in contaminant levels between sites. In addition, octachlorostyrene levels were greatest in the bluntnose minnows with a maximum value of 198 ppb in whole fish from the St. Clair River, five kilometres south of Chemical Valley.

At Brock University, a WTF project has led to the development of new tools for assessing the shock loading of pollutants in industrial effluent. Further, the project has involved a local industry in addressing pollution problems in the Welland River. At the University of Ottawa, new techniques for monitoring dioxins in wildlife, particularly Herring Gulls, are being explored. The results indicate that the Vitamin A level in the gulls is an indicator of the effects of dioxin-like compounds and may be used in environmental monitoring for dioxins.

At the University of Toronto, a model of the flow of contaminants in the Great Lakes region is being developed. The model should help to protect wildlife from excessive contamination by closely and quantitatively linking source to target and by enabling wildlife to be used as biomonitors of the general state of contamination.

Finally, University of Guelph researchers are documenting the effect of Lake Ontario contaminants on Snapping Turtles. Initial results show significant contamination of turtle eggs and turtle tissues taken from a site at Hamilton Harbour. Turtle hatchlings

from Hamilton Harbour and Cranberry Marsh on Lake Ontario also showed much greater incidences of deformities than hatchlings from Lake Erie and Algonquin Park. Based on the results of this project, the Canadian Wildlife Service is now exploring the use of Snapping Turtles as biomonitors.

Acid Rain: WTF projects are providing insights into the mobilization of metals by acid rain and the effects of acidification on wetlands, birds and forests.

In research conducted by scientists from the University of Toronto, the results show a sharp decline in reproductive success for Tree Swallows nesting around lakes with high acidity levels. For those lakes which were allowed to return to normal acidity levels, a return to normal reproductivity for nesting birds was noted.

Research has also documented the existence in wildlife of numerous metals mobilized by acid rain. In one project, the fecal pellets of deer from areas susceptible to the effects of acid rain were found to have a higher cadmium content than those sites which were not as sensitive to acid rain.

Work at the University of Toronto is also documenting metal accumulations in a number of wildlife species, including chironomid larvae and emergent chironomids, crayfish tissues, fish tissues and several species of mammals. Included among the results is the finding that the average concentrations of zinc were lower, whereas concentrations of cadmium were up to a magnitude greater in the gills of crayfish from acidic versus non-acidic lakes.

Prairie Pesticide Use: A number of projects are investigating the effects of pesticides on prairie sloughs and wildlife. Canadian concern for the health of Prairie waterfowl was recently highlighted with the approval of the North American Waterfowl Management Plan, representing a commitment of more than $1 billion over 15 years to waterfowl habitat conservation.

In a project at the University of Saskatchewan, researchers are assessing the impact of carbofuran on terrestrial prairie wildlife. Initial results showed a reduction in the functioning of brain enzymes from 45 to 60 percent, generally with recovery to normal levels in a very short time.

In a related project, researchers from the University of Guelph are addressing the impact of carbofuran spraying on mallard ducklings. One objective is to determine if invertebrates, contaminated with carbofuran, are important in causing duckling

mortality. Researchers from McGill University are also investigating the effects of the pesticide bromoxynil on a prairie wetland ecosystem and have documented significant impacts on pond algae.

Forest Herbicide Use: Research is also underway to document the effects of forest herbicides on small mammals.

Researchers at Dalhousie University have determined that use of the herbicide glyphosate led to a decline in two bird species, the alder flycatcher and the mourning warbler. However, these species continued to breed on the sprayed plot and there was no evidence of a decrease for other species. A post-breeding bird census indicated that there was a significantly higher density of birds in unsprayed areas than in those that had been sprayed with glyphosate.

In Alberta, a multi-year study on the impact of hexazinone herbicide has failed to document any acute toxicity effects based on animal abundance within ten days of treatment with the herbicide.

Heavy Metals in the Environment: Two projects are investigating the effects of heavy metals in ungulates (moose and deer) at a time when advisories have been sent out to hunters cautioning them about this problem.

At the University of Western Ontario, Dr. George Cherian has documented an age-dependent increase in cadmium and metallothionein accumulation in moose liver and kidney. He has also shown that the accumulation of cadmium in the kidneys of ungulates increased three-fold in areas of high acid precipitation.

In another project, researchers from the University of Manitoba are determining the effects of atmospheric metal deposition from a heavy metal smelter at Flin Flon, Manitoba on aquatic organisms. Present results indicate that acclimation to metal exposure has occurred in organisms from the study lakes. However, the researchers note that the potential for long-term detrimental effects of atmospheric metal deposition on the lakes cannot be discounted.

Additional Wildlife Toxicology Issues: A number of other wildlife toxicology concerns have also been addressed by the Wildlife Toxicology Fund.

Canada's coastal waters currently receive large quantities of man-made wastes and chemicals and thus the issue of marine

ecosystem health is a key one. Included among the projects underway is one by scientists at the University of Victoria who are studying the uptake of metals by a various species of mussels. On the east coast, researchers at the St. Lawrence National Institute for Ecotoxicology are asessing contaminant types and levels in marine mammals which have been washed up along the shores of the St. Lawrence.

The contamination of Arctic wildlife has also been a concern. Researchers at the University of Alberta have been funded by the WTF to assess contamination levels in Peregrine Falcons located in the Keewatin District of the Northwest Territories. The results indicated that eggshells from 88 eggs representing 65 clutches of 26 pairs from 1981 to 1985 average 14 percent thinner than eggs collected prior to 1947; only four percent below thinning levels considered critical for successful reproduction. It is suspected that DDE residues are being accumulated by peregrines during their migrations to Latin America.

Relevance to National and International Environmental Concerns

The policy implications of work funded by the WTF are becoming increasingly clear as results from the initial projects are received. The results will be important to non-government organizations, provincial governments and to Environment Canada as strategies for the management of toxic chemicals are developed and implemented. Some examples of the environmental management implications of work funded by the WTF include:

<u>Clean-up of the St. Lawrence River and Estuary</u>:
The federal government recently announced a $110 million commitment for the clean-up of the St. Lawrence River and the province of Quebec is committing $3 billion over the next ten years. At least two WTF projects will provide important research data to guide the clean-up effort. Dr. Pierre Beland of the St. Lawrence National Institute of Ecotoxicology at Rimouski is assessing contamination levels in a number of marine mammal species found in the St. Lawrence. The project will provide the first comprehensive evaluation of contamination by polycyclic aromatic hydrocarbons in marine mammal carcasses found along the shores of the St. Lawrence. Dr. Jean Bedard, at Laval University, is assessing contaminants in Razorbill Auks, a fish-eating seabird found in the St. Lawrence estuary. Other WTF projects indirectly provide techniques and information important to understanding and monitoring the effects of contamination in the St. Lawrence River and its estuary.

Management of Chemicals:
WTF research is contributing to the knowledge necessary for the regulation of pesticides and their use. In one project, Dr. David Bird, of McGill University, has shown that use of the pesticide Dicofol is associated with eggshell thinning, increased shell breakage, reduced fertility and reduced nest hatching success of exposed eggs. As a result of the WTF, information on the wildlife impacts of numerous other commercial chemical products including malathion, pentachlorophenol, carbofuran, deltamethrin, glyphosate, hexazinone and bromoxynil octanoate is being assembled. Such information will be extremely valuable to Environment Canada as the Department undertakes its regulatory responsibility for "cradle-to-grave" management of manufactured toxic chemicals under the Pest Control Products Act and the new Canadian Environmental Protection Act.

Long Range Transport of Airborne Pollutants:
WTF researchers are contributing information useful to Environment Canada's program on the Long Range Transport of Airborne Pollutants. Two projects at the University of Toronto are assessing the use of lichen and lower plants to monitor air deposition of trace organics. At the University of Quebec at Montreal, researchers are looking at the impact of atmospheric pollution on forest dieback and its resulting effect on insect-eating bird species. Further, York University scientists are exploring the impact of airborne chlorinated hydrocarbons on aquatic ecosystems. It is believed that the discovery of a high correlation between high nutrient levels in a lake and low levels of PCBs will have important implications for the management of eutrophic lake systems.

Great Lakes Water Quality:
The utility of wildlife as biomonitors of Great Lakes pollution is being evaluated in a number of WTF projects. It is expected that the results will be useful to government scientists in monitoring compliance with the Great Lakes Water Quality Agreement. In addition, the toxic modelling work being carried out by Dr. Donald Mackay, of the University of Toronto in collaboration with scientists from the Canadian Wildlife Service, is providing a broader framework for assessing lake contamination. Through these projects, wildlife species are serving as warning signals for potential trouble spots with respect to both human health and the ecosystem.

Endangered Species:
Environment Canada's commitment to the recovery of Canada's endangered species was reaffirmed in 1987 with the Minister's agreement to participate in the Endangered Species Recovery Fund. In addition, recovery programs for a number of species, including

the endangered Peregrine Falcon, are already underway. WTF research on pesticide residues in peregrines, as well as in the raptor's food sources, is providing valuable baseline data for the department as it designs and implements its recovery effort for the bird. Research on the impact of strychnine (used in Ground Squirrel control) on Saskatchewan's Burrowing Owl population will also provide data useful to the federal, provincial and non-governmental efforts to boost the recovery odds for this threatened species. Further, work on the toxic contamination of fish-eating birds in Manitoba has implications for the White Pelican, the first species to be removed from Canada's list of endangered species. The WTF research will help to ensure that the successful recovery of the bird is sustained.

The Wildlife Toxicology Fund as Catalyst

In addition to the quality and relevance of the WTF research that has been funded to date, the collaborative nature of the grant program has made it extremely successful. The linkage of the private sector, a non-governmental organization and the federal government has proven to be an effective mechanism for addressing a key environmental concern. It has also catalyzed contributions from many other players for wildlife toxicology research.

Moreover, the WTF may be regarded as a forerunner of the type of tripartite partnerships recommended by the Report of the World Commission on Environment and Development and by the Canadian response to that report prepared by the National Task Force on Environment and Economy. Such partnerships demonstrate the integral relationship between environmental and economic interests. By stretching scarce government dollars and securing the moral and financial support of a number of corporate partners, the Wildlife Toxicology Fund is successfully addressing an environmental issue of growing magnitude and concern in Canada.

Matching Funds

Through its matching funds requirement, the WTF has secured financial commitments from a number of outside funders for wildlife toxicology research. Provincial ministries have continued to play a major role (30% of all outside funds) in matching the support of the Department of the Environment. In a number of cases, funding from the Wildlife Toxicology Fund prompted this provincial commitment to wildlife toxicology. A contribution of $20,000 per year for three years has been made by Alcan Aluminum Ltd. This support is being directed to Dr. Pierre

Beland's work on the toxic contamination of St. Lawrence marine mammals. In the past, matching funds have been received from Hoechst Canada Ltd., Byron Creek Collieries Ltd, Line Creek-Crowsnest Resources Ltd., May & Baker Canada Ltd. and the Petroleum Association for the Conservation of the Environment. WWF continues to seek matching funds from other corporate supporters. NSERC and other federal departments have also played a role in supporting WTF projects.

Spreading the Word

Dissemination of results obtained from WTF projects has been a priority since the outset of the grant program. Now that the projects funded in the initial years are drawing to a close, we are actively ensuring that the research results reach the appropriate policy and management bodies in both the public and private sectors. For each project, specific contacts are being identified. As the final reports on projects are received, they will be forwarded to the appropriate agencies and individuals. In addition, all researchers are required to secure publication of their findings in top scientific journals. A recent journal article by WTF researcher, Dr. Don Mackay, of the University of Toronto, and his collaborators is attached as Appendix B.

In addition to the dissemination efforts for individual projects, WWF will be compiling the final reports for all projects funded during the first three years of the WTF. A number of sets of these reports will be printed and distributed to selected libraries specializing in wildlife toxicology issues, as well as to regional offices of the Canadian Wildlife Service, and relevant provincial agencies.

To date, WWF has held two seminars at which WTF researchers reported on their work. The first was held in Ottawa in April of 1987 and the second was held in Saskatoon in October of 1987. Interested government and academic scientists were encouraged to attend the events and good attendance was registered at both seminars. The sessions provided an excellent opportunity to draw together scientists working on specific priority concerns of the WTF. For example, one session dealt with the impact of Great Lakes contamination on wildlife and the other with the effect of pesticides on Prairie wildlife, both terrestrial and aquatic. Additional seminars are now being planned.

In addition to the dissemination strategies outlined above, WWF is continuing to prepare short feature stories for the news media on projects supported by the WTF. The news release for the second annual report of the WTF received excellent coverage and a sample of these news clippings is attached as Appendix C. Regular

articles appear in WWF's quarterly newspaper Working for Wildlife and the WTF is given prominent mention in WWF's Annual Report. The program has also been featured in the 1986 and 1987 annual reviews of WWF International. As a result, there has been great interest in the WTF from a number of the other 22 countries which comprise the WWF family.

The Future

As the result of a very productive first phase, World Wildlife Fund and Environment Canada have agreed to renew the Wildlife Toxicology Fund for a second three-year period. Based on a mutual decision to broaden the core funding base of the WTF, Environment Canada has agreed to provide $1 million over three years for the grant program and WWF has committed itself to raising at least $200,000 per year over three years from other sources. WWF has already received funding pledges from the Ontario Ministry of the Environment, the Quebec Ministry of the Environment, Alcan Aluminum Ltd. and Fisheries and Oceans Canada. Thus, the WTF will operate with core funding of at least $533,000 in each year for the next three years.

Under the new agreement, research supported by the Wildlife Toxicology Fund must aim to produce information useful for:

1. Assessment of substances on the Priority Substances List of the Canadian Environmental Protection Act and corresponding Acts of the participating Provincial Governments.

2. Pesticides, both chemical and microbial, on DOE's priority list for review under the Pest Control Products Act or equivalent priorities identified by participating provincial governments.

3. Topics of concern identified by the Long Range Transport of Airborne Pollutants Program.

The WTF will continue to operate as a matching fund, with research proposals being funded to a maximum of 50% of the cost of the project. The balance of the funding may be from any source, public or private.

The first three years established the value and merit of the Wildlife Toxicology Fund. The grant program has now reached maturity and WWF looks ahead with anticipation and determination to the next three years. In many areas, we are just beginning to shed light on the complex and often subtle and long-term effects that toxic chemicals are having on wildlife. Much remains to be

done. The opportunity to continue working with Environment Canada and the private sector to further develop this significant grant program is most welcome.

Appendix A

WTF Projects Approved for Funding as of March 31, 1988

Project Title	Co-ordinator	85-86 WTF	85-86 Matching	86-87 WTF	86-87 Matching	87-88 WTF	87-88 Matching	Total WTF	Total Matching
1. "Bioassays For Toxicology of Petroleum Oil to Sea Birds"	Dr. F. Leighton/ U. of Sask.	$ 49,000	$ 40,000	$ 42,200	$ 69,300			$ 91,200	$ 109,300
2. "Potential Transfer of Metals from Lakes to Mammals, Birds & Reptiles"	Dr. H. Harvey/ U. of Toronto	$ 28,300	$ 28,613	$ 24,151	$ 39,975	$ 10,000	$ 10,000	$ 62,451	$ 78,588
3. "Fluorosis in American Kestrels"	Dr. D. Bird/ McGill University	$ 19,820	$ 22,475					$ 19,820	$ 22,475
4. "Speciation of Lead in Pigeons"	Dr. W.D. Marshall/ McGill University	$ 36,715	$ 36,924					$ 36,715	$ 36,924
5. "Mechanisms of Metal Cycling Between Aquatic Insects & Terrestrial Wildlife"	Dr. P. Stokes/ U. of Toronto	$ 8,100	$ 14,150					$ 8,100	$ 14,150
6. "Contaminant Impacts Assessed by the Biomass Size Spectrum"	Dr. G. Sprules/ U. of Toronto	$ 25,515	$ 31,115	$ 23,263	$ 23,262	$ 25,013	$ 23,013	$ 73,791	$ 79,390
7. "Effects of PCP on Gammarus Tigrinus"	Dr. F. Baerlocher/ Mount Allison U.	$ 15,000	$ 16,100					$ 15,000	$ 16,100
8. "Biological Significance of Trace Metals in Sediments"	Dr. A. Tessier/ U. du Quebec	$ 30,000	$ 73,000	$ 30,000	$ 74,000	$ 30,000	$ 72,800	$ 90,000	$ 219,800
9. "Hydrocarbon & Organohalogen Pollutants in a Shorebird Food Resource"	Dr. R.G. Ackman/ Technical U. of Nova Scotia	$ 3,500	$ 3,500					$ 3,500	$ 3,500

	Project Title	Co-ordinator	85-86 WTF	85-86 Matching	86-87 WTF	86-87 Matching	87-88 WTF	87-88 Matching	Total WTF	Total Matching
10.	"Levels of Toxic Chemicals in Selected Birds in Manitoba"	Dr. M. Shoesmith/ U. of Manitoba	$ 12,500	$ 14,000	$ 28,793	$ 28,793	$ 18,000	$ 33,300	$ 59,293	$ 76,093
11.	"Study of the Effects of Toxic Metal Pollutants on a Cellular System Pertinent to Aquatic Wildlife"	Dr. F. Denizeau/ U. of Quebec	$ 11,000	$ 14,000	$ 25,500	$ 30,910	$ 13,500	$ 16,500	$ 50,000	$ 61,410
12.	"The Significance of Neoplasia in Wild Fish Populations"	Dr. M. Hayes/ U. of Guelph	$ 34,290	$124,650	$ 41,750	$ 62,250			$ 76,040	$ 186,900
13.	"Environmental Toxicology of the Welland River Wetland Area"	Dr. M. Dickman/ Brock University	$ 39,000	$123,000	$ 49,000	$ 257,000	$ 61,000	$ 26,000	$ 149,000	$ 406,000
14.	"Biomonitoring of Chlorinated Hydrocarbons in the Huron-Erie Corridor"	Dr. P. Hebert/ U. of Windsor	$ 49,000	$ 88,000	$ 49,000	$ 88,000	$ 52,000	$ 88,000	$ 150,000	$ 264,000
15.	"The Pharmacological Effects & Ecological Implications of Malathion induced Cholinesterase Inhibition Determined from Field & Laboratory Studies"	Dr. F.J. Ward/ U. of Manitoba	$ 21,762	$ 25,412	$ 21,762	$ 25,412			$ 43,524	$ 50,824
16.	"Cadmium Burdens in Deer Browse, Pellets and Soil"	Dr. G. Parker/ Laurentian U.	$ 9,000	$ 9,000					$ 9,000	$ 9,000

	Project Title	Co-ordinator	85-86 WTF	85-86 Matching	86-87 WTF	86-87 Matching	87-88 WTF	87-88 Matching	Total WTF	Total Matching
17.	"The Effects of Deltamethrin on Prairie Ponds & Duck Populations"	Dr. B.R. Neal/ U. of Sask.	$ 40,000	$ 64,000	$ 22,000	$ 22,000	$ 25,075	$ 25,075	$ 87,075	$ 111,075
18.	"Fate of Carbofuran in Prairie Ponds & its Effects on Aquatic Invertebrates"	Dr. D.A. Boag/ U. of Alberta	$ 10,600	$ 35,140					$ 10,600	$ 35,140
19.	"Monitoring of Heavy Metal Exposure in Moose & other Wildlife Populations in Ontario"	Dr. M.G. Cherian/ U. of Western Ont.	$ 15,400	$ 15,400	$ 15,400	$ 15,400	$ 15,400	$ 15,400	$ 46,200	$ 46,200
20.	"Development of Models Describing the Dynamics of Toxic Organic Chemicals in the Environment & Wildlife of the Great Lakes Basin"	Dr. D. Mackay/ U. of Toronto	$ 48,000	$110,000	$ 48,000	$ 110,000	$ 44,000		$ 140,000	$ 220,000
21.	"Toxins in Rocky Mountain Forage Legumes: A Preliminary Assessment"	Dr. M.A.M. Bell/ U. of Victoria	$ 4,264	$ 32,946	$ 4,760	$ 25,300			$ 9,024	$ 58,246
22.	"The Mortality of Amphibians in Ponds near Sudbury"	Dr. D.G. McDonald/ McMaster University			$ 4,500	$ 4,500			$ 4,500	$ 4,500
23.	"Exposure Indicators for Metals Discharged by a Smelter"	Dr. J. Klaverkamp/ U. of Manitoba			$ 23,200	$ 23,200	$ 18,900	$ 18,900	$ 42,100	$ 42,100
24.	"Cadmium Burden and Its Effects on Birds"	Dr. R. Johnson/ Trent University			$ 11,697	$ 11,698	$ 11,653	$ 11,652	$ 23,350	$ 23,350

Project Title	Co-ordinator	85-86 WTF	85-86 Matching	86-87 WTF	86-87 Matching	87-88 WTF	87-88 Matching	Total WTF	Total Matching
25. "Toxicology of Chlorophenols to Zooplankton and Macrobenthos"	Dr. K. Solomon/ U. of Guelph			$ 30,000	$ 30,000	$ 27,000	$ 27,000	$ 57,000	$ 57,000
26. "Acidification of a Freshwater Wetland"	Dr. S. Bayley/ U. of Manitoba			$ 30,000	$ 64,465	$ 35,000	$ 65,896	$ 65,000	$ 130,361
27. "The Effects of Lake Acidification on Avian Species"	Dr. J.C. Barlow/ U. of Toronto			$ 10,134	$ 10,500	$ 9,500	$ 10,500	$ 19,634	$ 21,000
28. "Retinoid Monitoring For Dioxins and Related Compounds"	Dr. T. Moon/ U. of Ottawa			$ 20,000	$ 54,390	$ 30,000	$ 40,285	$ 50,000	$ 94,675
29. "Radioactive Pollutants in the Ecosystems of Wood Buffalo National Park"	Dr. J. Svoboda/ U. of Toronto			$ 13,500	$ 13,500	$ 14,250	$ 14,250	$ 27,750	$ 27,750
30. "Effects of Hexazinone Herbicide on Small Mammal Populations"	Dr. D. Penner/ McCourt Management Ltd., Edmonton			$ 30,000	$ 58,000	$ 25,000	$ 57,000	$ 55,000	$ 115,000
31. "Effects of Grasshopper Insecticides Upon Valuable Wildlife"	Dr. D.G. Irvine/ U. of Sask.			$ 42,995	$ 62,150	$ 39,250	$ 49,750	$ 82,245	$ 111,900
32. "Snapping Turltes as Biomonitors of Organochlorine Contamination in Wetlands"	Dr. R. Brooks/ U. of Guelph			$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 30,000	$ 30,000
33. "Impact of Airborne Chlorinated Hydrocarbons in Aquatic Ecosystems"	Dr. D. McQueen/ York University			$ 45,654	$ 45,654			$ 45,654	$ 45,654

	Project Title	Co-ordinator	85-86 WTF	85-86 Matching	86-87 WTF	86-87 Matching	87-88 WTF	87-88 Matching	Total WTF	Total Matching
34.	"Metal Sequestration in Marine Bivalves of the N.E. Pacific"	Dr. R. Reid/ U. of Victoria			$ 15,076	$ 14,930	$ 14,913	$ 25,111	$ 29,989	$ 40,041
35.	"Biological Monitoring for Airborne Organic and Metal Contaminants in the Upper Great Lakes Region of North America"	Dr. Pamela Stokes/ U. of Toronto			$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 30,000	$ 30,000
36.	"Toxicology of Peregrine Falcons in Keewatin District of the N.W.T."	Dr. D.A. Boag/ U. of Alberta			$ 20,150	$ 31,000		$	$ 20,150	$ 31,000
37.	"Feeding Ecology of Wintering Herring Gulls"	Dr. Erica Nol/ Trent University			$ 625	$ 625	$ 437	$ 437	$ 1,062	$ 1,062
38.	"A Study of Cadmium in Wildlife in Manitoba"	Mr. Paul Paquet/ Riding Mountain Biosphere Reserve			$ 21,000	$ 27,700	$ 21,000	$ 27,700	$ 42,000	$ 55,400
39.	"Novel Use of Stress-Induced Morphological Abnormalities in Lichens as an Early Warning of Forest Decline"	Dr. Tom Hutchinson/ U. of Toronto			$ 48,500	$ 48,500	$ 48,500	$ 48,500	$ 97,000	$ 97,000
40.	"Metal Contamination of Wetland Food Chains in the Bay of Quinte"	Dr. Adele Crowder/ Queen's University			$ 21,550	$ 21,550	$ 21,043	$ 21,043	$ 42,593	$ 42,593

	Project Title	Co-ordinator	85-86 WTF	85-86 Matching	86-87 WTF	86-87 Matching	87-88 WTF	87-88 Matching	Total WTF	Total Matching
41.	"Effects of Silvicultural Glyphosate Spraying on Breeding Birds and Small Mammals"	Dr. Bill Freedman/ Dalhousie University			$ 10,000	$ 10,000	$ 6,850	$ 6,850	$ 16,850	$ 16,850
42.	"In Situ Studies of the Effects and Persistence of Bromoxynil Octanoate on Prairie Wetlands"	Dr. Rodger Titman/ McGill University			$ 14,092	$ 21,100	$ 8,964	$ 2,000	$ 23,056	$ 23,100
43.	"The Impact of Forest Decline on Insectivorous Birds"	Dr. Y. Mauffette, U. of Quebec at Montreal					$ 40,000	$ 108,176	$ 40,000	$ 108,176
44.	"Effects of Dicofol on Kestrels"	Dr. D. Bird/McGill University					$ 48,482	$ 79,646	$ 48,482	$ 79,646
45.	"Effects of Fenitrothion on Zebra Finches"	Dr. P. Boag/Queen's University					$ 22,650	$ 38,000	$ 22,650	$ 38,000
46.	"Mercury Pathways, the Role of Benthic Invertebrates"	Dr. P. Stokes/U. of Toronto					$ 22,416	$ 30,800	$ 22,416	$ 30,800
47.	"Dynamics of Organic Contaminants Uptake by Natural Seston"	Dr. H. Peters/McGill University					$ 15,460	$ 15,901	$ 15,460	$ 15,901
48.	"Contaminants and Population Trends in Razorbill Auks"	Dr. J.H. Bedard/Laval University					$ 10,650	$ 10,758	$ 10,650	$ 10,758
49.	"Effects of Hexazinone Herbicide on Small Mammal Populations"	Dr. D. Penner/Penner & Associates Ltd., Edmonton					$ 25,000	$ 52,762	$ 25,000	$ 52,762

	Project Title	Co-ordinator	85-86 WTF	85-86 Matching	86-87 WTF	86-87 Matching	87-88 WTF	87-88 Matching	Total WTF	Total Matching
41.	"Effects of Silvicultural Glyphosate Spraying on Breeding Birds and Small Mammals"	Dr. Bill Freedman/ Dalhousie University			$ 10,000	$ 10,000	$ 6,850	$ 6,850	$ 16,850	$ 16,850
42.	"In Situ Studies of the Effects and Persistence of Bromoxynil Octanoate on Prairie Wetlands"	Dr. Rodger Titman/ McGill University			$ 14,092	$ 21,100	$ 8,964	$ 2,000	$ 23,056	$ 23,100
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48.	"Contaminants and Population Trends in Razorbill Auks"	Dr. J.H. Bedard/Laval University					$ 10,650	$ 10,758	$ 10,650	$ 10,758
49.	"Effects of Hexazinone Herbicide on Small Mammal Populations"	Dr. D. Penner/Penner & Associates Ltd., Edmonton					$ 25,000	$ 52,762	$ 25,000	$ 52,762

	Project Title	Co-ordinator	85-86 WTF	85-86 Matching	86-87 WTF	86-87 Matching	87-88 WTF	87-88 Matching	Total WTF	Total Matching
50.	"Carbofuran in Mallard Ducklings"	Dr. K. Solomon/ U. of Guelph					$ 7,222	$ 19,000	$ 7,222	$ 19,000
51.	"Effects of Strychnine on Burrowing Owls"	Dr. P. James/Sask. Museum of Natural History					$ 5,000	$ 5,000	$ 5,000	$ 5,000
52.	"Toxicology & Pathology of St. Lawrence Marine Mammals"	Dr. P. Beland/ St. Lawrence Nat'l Inst. of Ecotoxicology					$ 75,000	$ 120,000	$ 75,000	$ 120,000
53.	"Radiation levels in the Cape Churchill Caribou"	Ms. B. Draper/ Institute of Arctic Ecophysiology					$ 300	$ 600	$ 300	$ 600
		Totals	$510,766	$921,425	$868,252	$1,455,064	$928,428	$1,249,605	$2,307,446	$3,626,094

Grand Total = $5,933,540

WTF provided $140,000 for this project.

ES&T
FEATURES

Appendix B

Wildlife monitoring, modeling, and fugacity

They are indicators of chemical contamination

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Observations of wildlife populations and their state of health have played a key role in identifying situations in which chemical contaminants have reached unacceptable concentrations in the environment. The reproductive failure of several species—including the peregrine falcon (*Falco peregrinus*), the double crested cormorant (*Phalocrocorax auritus*), the brown pelican (*Pelicanus occidentalis*), and the osprey (*Pandion haliaetus*)—has been attributed to organochlorine contamination (*1–6*). Other examples have been cited by Kendall in his review of wildlife toxicology (*7*), and by Wren in a discussion of mammals as monitors of metal contamination (*8*). As the mine canary can warn of the presence of a poisonous gas in a coal mine, wildlife populations can act as sentinels for excessive chemical contamination.

This blunt and often tragic exploitation of wildlife as a sentinel is, to be sure, an extreme example of the more subtle and far-reaching issue of the extent to which wildlife tissues can be used to indicate general levels of environmental contamination and provide guidance to the scientific and regulatory communities about the state of the environment. There are two quite sepa-

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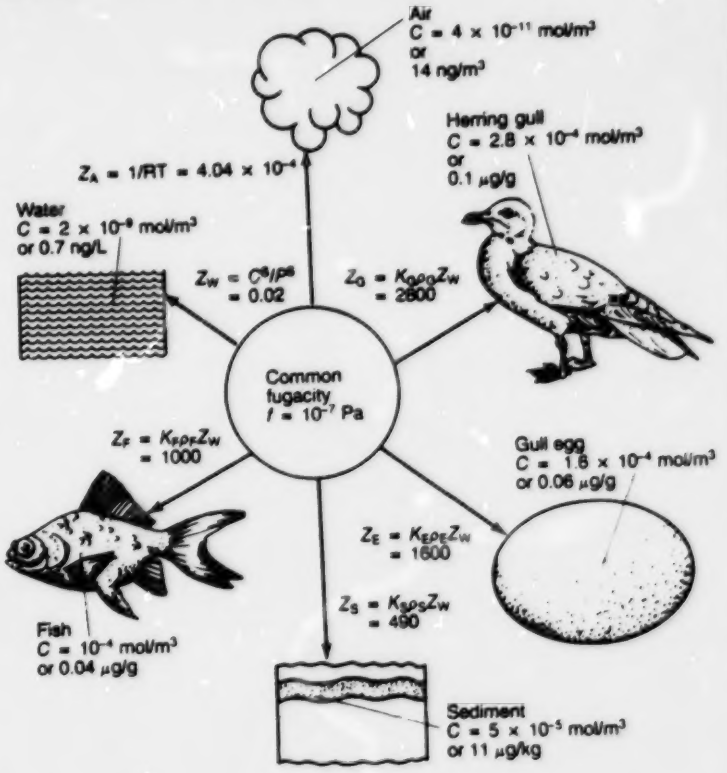
FIGURE 1
Equilibrium distribution of a hypothetical compound[a]



[a]The compound is distributed between various media in the Lake Ontario region.
Properties of compound used to calculate Z values (mol/m³ Pa):
Molecular weight = 350 g/mol
Solubility C^S = 10^{-1} mol/m³
Vapor pressure P^S = 5×10^{-3} Pa
Partition coefficients:
Octanol/water K_{OW} = 10^5
Fish/water K_F = 0.05 K_{OW}
Gull/water K_G = 0.14 K_{OW}
Gull egg/water K_E = 0.08 K_{OW}
Sediment/water K_S = 0.411 K_{OW} F_{OC}
Densities (kg/L)
Fish ρ_F = 1.0
Gull ρ_G = 1.0
Gull egg ρ_E = 1.0
Sediment ρ_S = 1.5
F_{OC} = fraction of organic material in sediment = 0.04
Concentration C = fZ (mol/m³)
R = 8.314 J/mol K
T = 298 K

rate motives for exploring this issue.

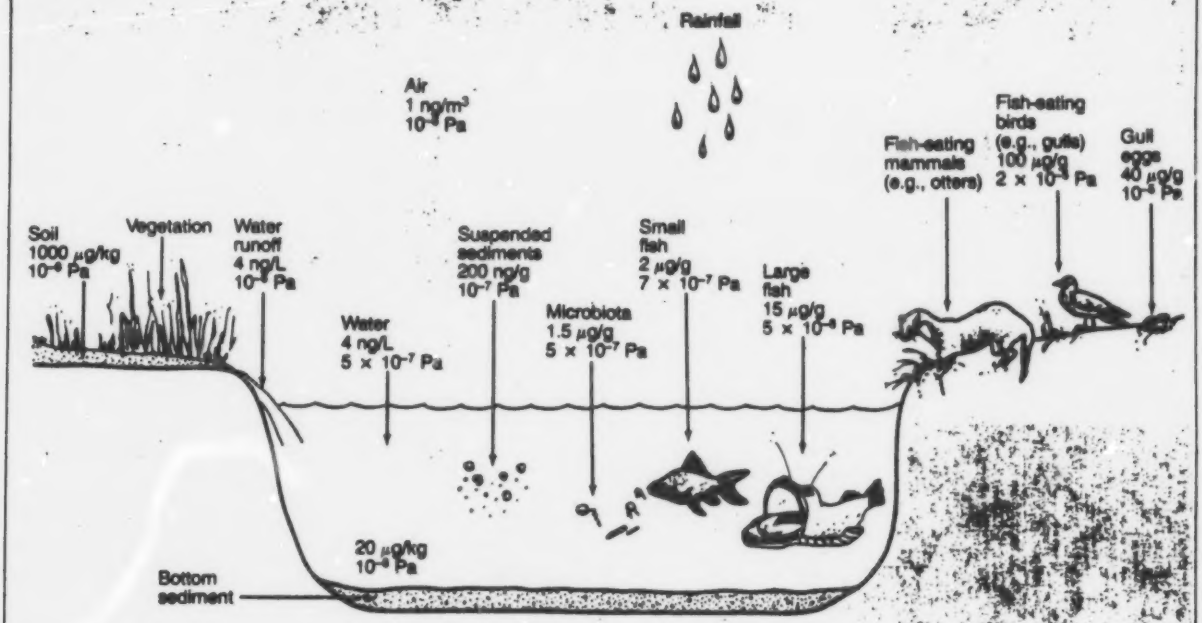
First, we value wildlife for its own sake, both aesthetically and economically. Restrictions on sport and commercial fishing in the Great Lakes basin have had dramatic effects on many small communities. The public is particularly angered by evidence that charismatic species (the ones with big, brown, sad eyes) are at risk. The extinction or extirpation of a species such as the peregrine falcon in eastern North America also is a genetic tragedy. Surely, it is argued, we should be able to ensure a continuing healthful environment for species that have carved out a niche for themselves over evolutionary millennia, long before the advent of organochlorines. Many would insist that we have an obligation to preserve these species and their ecological niches.

Second, analysis of tissues of wildlife or other sentinel organisms can provide a long-term picture of the state of contamination, its increase or decrease, and the arrival (often unexpected) of new contaminants. Tissues can be archived for retrospective analysis. For certain instances of contamination, conventional abiotic analyses can be complemented or even replaced by tissue analyses of organisms that integrate and concentrate contaminants. This can lead to easier, less expensive, and more representative analyses.

One example is the Mussel Watch program (*9*) in which bivalves from over 100 stations in the United States are monitored for concentrations of petroleum hydrocarbons, chlorinated hydrocarbons, and heavy metals that may affect the health of the public or marine life. Another example is the herring gull program in the Great Lakes (*10*). After the recent Chernobyl disaster, the West German monitoring program used archived lichen samples to determine levels of radioactivity that existed before the accident. Biological monitoring is well-established as an invaluable component of environmental surveillance (*11*).

The use of contaminant concentrations in wildlife tissue as an indicator of environmental concentrations is predicated on an assumption that for each chemical there exists some fairly constant ratio of tissue to environmental concentration; that is, a type of bioconcentration factor. For example, contaminant concentrations in fish presumably are related to concentrations in water and food (and possibly in sediment) in a predictable, quantifiable way. Establishing a picture of the bioconcentration

FIGURE 2
Concentrations and corresponding fugacities of the chemical[a]



[a]The compound is the chemical depicted in Figure 1 and distributed between various environmental media; fugacities are expressed in Pa.

pathway from source to target, however, can be tortuous and subject to many pitfalls.

Avoiding these pitfalls requires two sets of basic information. The fundamental biology, ecology, or natural history of the animal must be thoroughly understood because factors such as feeding habits, migration or mobility, and changes in lipid content can influence concentrations in tissues. Second, the rates of uptake, clearance, and metabolism (toxicokinetics) must be understood so that the status of the organism with respect to equilibrium or steady state may be determined. For example, the uptake time for some chemicals may exceed the lifetime of the organism, and a steady state is never reached. These rates are chemical-specific, but it is likely that extrapolations can be made from chemical to chemical through the careful use of structure–activity relationships.

A wildlife biomonitor must have a well-understood natural history and toxicokinetics in addition to other desirable features such as ease of sampling, tendency to remain in a locality, and ability to survive exposure to the levels of contaminant being monitored. Other factors to be considered are commercial importance or charismatic appeal.

Monitoring and modeling

Recent advances in biomonitoring sophistication have coincided with increases in the use and acceptance of multimedia environmental models (*12*). It is now recognized that the regulation of chemicals in the environment must be based on an understanding of the mass balances that are established as chemicals originating from various sources migrate between water, air, sediments, soil, and biota. Accordingly, attempts are being made to repeat the success of the Lake Erie phosphorus models for other chemicals in the entire Great Lakes basin, notably for polychlorinated biphenyls (PCBs) and other persistent organic compounds (*13*, *14*). During the next decade, a capability of constructing verifiable mass balance models for most chemicals in defined regions likely will emerge.

Such models undoubtedly will exploit wildlife biomonitoring data; for many chemicals, such data may be the primary source of information. This is not to suggest that air, water, and sediment sampling will become unimportant. If reliable bioconcentration relationships can be shown to exist between water, fish, gulls, and gull eggs it may then become more convenient to monitor the state of the water by a strategy of routine analysis of gull eggs, coupled to a less comprehensive, confirmatory program of water analysis. Such procedures could result in considerable economies because biotic concentrations are higher and fewer analyses may be needed.

Currently, monitoring or investigative programs that involve various biotic and abiotic media are conducted by different agencies for different purposes, and they usually employ different methods. These programs often are poorly coordinated. Much fish sampling is done from the human food and health perspective. Bird sampling often is related to concerns about pesticide application. Water sampling may be done to ensure the safety of drinking water. Analysis of contaminants in wildlife usually is done by agencies with a mandate to preserve wildlife, not to control chemical effluents.

This lack of integration is understandable but unfortunate because wildlife monitoring and general environmental monitoring can be mutually supportive. With the aid of environmental models both types of monitoring can provide a much clearer picture of contaminant trends, pathways, and dynamics. We will explore how these disparate activities may come together and how fugacity modeling could play a key role in linking these methods of monitoring.

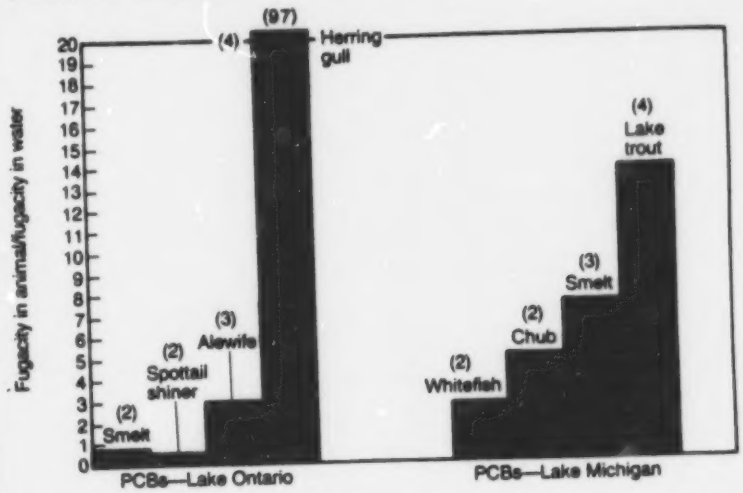
Fugacity

The concept of fugacity and its role in environmental models has been discussed in a series of papers (*15*–*17*).

Briefly, fugacity is analogous to chemical potential as it pertains to the tendency of a chemical to escape from a phase (e.g., from water). It is expressed in units of pressure (pascals) and is essentially a partial pressure exerted by the chemical in each medium. If a chemical attains concentrations in various media that are in equilibrium, its fugacity is equal in these media.

Fugacity f (Pa) is linearly related to concentration C (mol/m^3) through a proportionality constant, the fugacity capacity Z (mol/m^3 Pa), the value of which can be estimated for each chemical in each medium using established procedures (*15*). If we assume that a constant fugacity applies between various media and we can obtain the various Z values, it is possible for us to calculate the equilibrium concentrations and express them in commonly accepted units such as μg/kg, ppm, or ng/L (Figure 1). A nonequilibrium state usually exists in nature, however, because of localized emissions, ever-changing meteorological and hydrological conditions, and the nature and re-

FIGURE 3
Fugacity ratios of polychlorinated biphenyls (PCBs) in biota and water[a]



[a]Approximate trophic levels are indicated in parentheses.
Source: Reference 18.

TABLE 1
Concentrations and fugacities of selected organochlorine chemicals[a]

	Hexachlorobenzene	Mirex	*p,p'*-DDT	*p,p'*-DDE	Dieldrin	PCBs
Herring Gull (9.8–18% fat)[b]						
Total body concn (ppm)	0.18–0.26[b]	4.4–9.4[b]	0.029–0.15[b]	14–30[b]	0.18–0.53[b]	100–200[b]
Fat concn (mol/m^3)	0.0027–0.0076	0.042–0.14	0.00053–0.0037	0.23–0.79	0.0038–0.011	1.7–4.8
Fugacity (10^{-7} Pa)	700–2000	0.24–0.80	0.015–0.10	160–560	0.013–0.037	120–330
Egg (6.4–8.8% fat)[b]						
Total body concn (ppm)	0.068–0.14[b]	0.81–2.0[b]	0.013–0.050[b]	3.3–8.0[b]	0.067–0.18[b]	23–51[b]
Fat concn (mol/m^3)	0.0027–0.0060	0.016–0.043	0.00041–0.0016	0.11–0.27	0.002–0.0058	0.72–1.7
Fugacity (10^{-7} Pa)	720–1600	0.092–0.24	0.011–0.043	80–190	0.0065–0.019	51–120
Fish (alewife, 2.8% fat)[b]						
Total body concn (ppm)	0.005[b]	0.047[b]	0.015[b]	0.16[b]	0.017[b]	0.90[b]
Fat concn (mol/m^3)	0.0006	0.0029	0.0015	0.017	0.0015	0.087
Fugacity 10^{-7} Pa)	160	0.016	0.040	12	0.0051	6.1
Fish (smelt, 5.6% fat)[b]						
Total body concn (ppm)	0.005[b]	0.020[b]	0.014[b]	0.12[b]	0.016[b]	0.48[b]
Fat concn (mol/m^3)	0.0003	0.00061	0.00068	0.0061	0.00072	0.022
Fugacity (10^{-7} Pa)	77	0.0034	0.019	4.3	0.0024	1.5
Water						
Concn (ng/L)	0.01–0.12[e]	0.002[e]	0.03–0.27[e]	0.10[f]	0.26–0.63[e]	0.3–6
Fugacity (10^{-7} Pa)	3.7–44	0.0002	0.0022–0.020	0.022	0.0036–0.0086	0.29–5.7
Air						
Concn (ng/m^3)	0.1–0.3[g]	—	0.01–0.05[g]	—	0.01–0.1[g]	0.4–3.0[g]
Fugacity (10^{-7} Pa)	0.0087–0.026	—	0.00072–0.0036	—	0.000068–0.00066	0.03–0.21
Bottom sediment						
Concn (μg/kg)	10–320[h]	2–1600[i]	—	—	—	N.D.–113 ng/g[j]
Fugacity (10^{-7} Pa)	200–7200	0.0004–0.3	—	—	—	<0.55
Suspended sediment						
Concn (ng/g)	12–94[k]	3.9–18[k]	—	5.8–18[k]	—	0.1–4.0 ng/L[l]
Fugacity (10^{-7} Pa)	270–2100	0.011–0.049	—	0.31–0.97[l]	—	0.8–3.2

[a]In environmental media and wildlife in the Lake Ontario region.
[b]Reference 19.
[c]Reference 21.
[d]Reference 20.
[e]References 21 and 27.
[f]Reference 23.
[g]Reference 22.
[h]Reference 24 and 25.
[i]Reference 26.
[j]Reference 28.
[k]Reference 26.
[l]Reference 27.

TABLE 2
Physical–chemical properties and Z values of organochlorine compounds[a,b]

	Hexachlorobenzene	Mirex	p,p′-DDT	p,p′-DDE	Dieldrin	PCBs
Molecular weight	284.8	545.59	345.5	318	373.9	348.6
Solubility (mol/m³)	1.85×10^{-4}[c]	1.84×10^{-6}[c]	7.6×10^{-6}[d]	1.26×10^{-6}[d]	4.9×10^{-4}	10×10^{-6}
Vapor pressure (Pa)	0.173[c]	8.0×10^{-4}[c]	1.94×10^{-5}[d]	8.67×10^{-6}[d]	$2.67 \times 10^{-}$	$7 \times 10^{-}$
Log K_{ow}	5.5[e]	6.89[e]	5.97[e]	4.99[e]	6.20[e]	6
K_p (sediment)	1.64×10^{4}	3.9×10^{5}	3.84×10^{4}	4.02×10^{3}	$6.61 \times 10^{}$	
Z Values (mol/Pa m³):						
Air	4.03×10^{-4}	4.03×10^{-4}	4.03×10^{-4}	4.03×10^{-4}	$4.03 \times 10^{-}$	$03 \times 10^{-}$
Water	9.54×10^{-6}	0.23	0.392	0.145	1.91	0.0301
Sediment	2.34	1.34×10^{5}	2.25×10^{4}	876	$1.86 \times 10^{}$	1666
Gulls	5.16	2.43×10^{5}	4.97×10^{4}	1930	$4.11 \times 10^{}$	$8 \times 10^{}$
Gull eggs	2.91	1.37×10^{5}	2.8×10^{4}	1090	$2.31 \times 10^{}$	$1 \times 10^{}$
Alewife	1.07	5.02×10^{4}	1.03×10^{4}	399	$8.49 \times 10^{}$	4060
Smelt	2.16	1.01×10^{5}	2.08×10^{4}	807	$1.72 \times 10^{}$	

[a]Physical–chemical properties are estimated.
[b]*Z* values are calculated. The lipid contents given for biota in Table 1 are assumed in the calculations. The *Z* value for biota assuming the lipid behaves as though it were octanol: *Z* biota = lipid content × K_{ow} × *Z* water.
An organic carbon content of 0.10 was assumed for the bottom and suspended sediments. Thus, $K_p = 0.411(K_{ow})0.10$
[c]Reference 45.
[d]Reference 30.
[e]References 36 and 38.
[f]References 31 and 36–38.
[g]Reference 39.
[h]References 36–38.
[i]References 31 and 32.
[j]Reference 28.
[k]References 31 and 40.
[l]Reference 41.
[m]References 38, 40, 42, and 43.
[n]References 30, 33, and 34.
[o]Reference 33.
[p]References 33 and 36.
[q]Reference 44.

sistance of transfer processes between the various phases such as air, water, sediment, and fish (*15*).

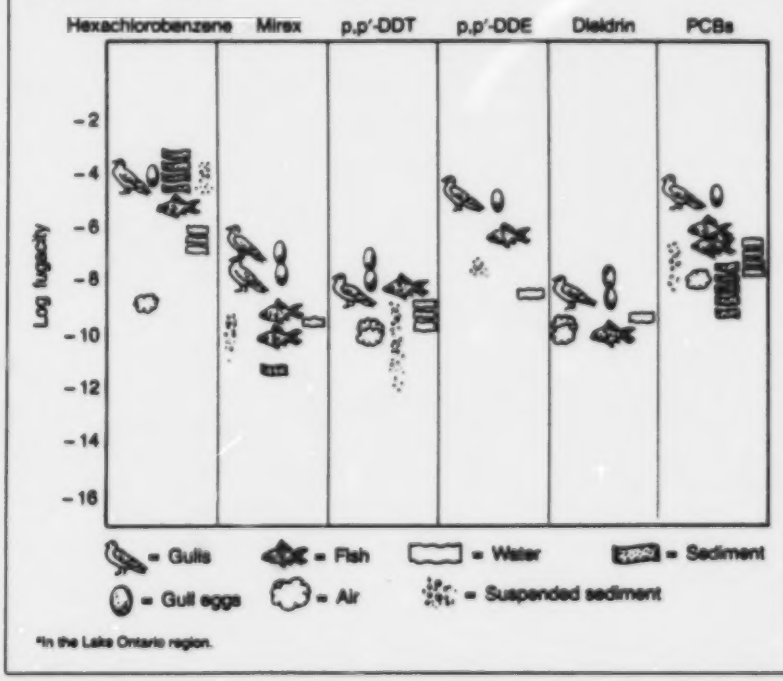
Levels of contamination in many media may be compared within a consistent single-unit system by converting reported environmental concentrations to fugacity. This synoptic fugacity approach reveals the equilibrium status of each medium with respect to the others. Hot spots that probably are sources of contamination can be identified, as well as areas that are relatively free of contamination. Compartments that approach equilibrium fugacity, or "equifugacity," are clearly identified; this is illustrated in a hypothetical example in Figure 2. The same information can be obtained by comparing phase concentrations with respect to their partition coefficients, but fugacity provides a simple, elegant, comprehensive multimedia picture of equilibrium status.

The synoptic fugacity concept

What roles can fugacity play in assessing concentrations of chemicals in the environment and in wildlife? To answer this question we will examine two sets of data. The first is a study from Connolly and Pedersen (*18*) in which concentrations of chemicals in varying trophic levels of fish were converted to fugacity and compared with water fugacity. These data, as presented in Figure 3 for PCBs in Lake Michigan, show that fugacity in water and fish generally are similar, but also that there is a definite trend for fugacity to increase with increasing trophic level. Also shown in Figure 3 in a similar manner are data from Lake Ontario (Table 1).

Table 1 presents concentrations of various organochlorine chemicals in environmental media and wildlife in the Lake Ontario region, as well as ranges of percentage lipid content for herring gulls and their eggs, alewife, and smelt. Using the data in Table 2 we may convert these concentrations to fugacities; it is assumed that the contaminant is

FIGURE 4
Fugacity of compounds in various media[a]



[a]In the Lake Ontario region.

present primarily in the lipid. Both sets of data broadly show that fugacity appears to increase with trophic level.

These examples reveal some of the benefits derived from using fugacity. Table I presents concentration units typical of most studies; for instance, herring gull contamination is reported in mg/kg and water contamination in ng/L. Data expressed in these units are not easily compared. The PCB level in herring gulls (Table I), for example, is about 150 mg/kg (whole-body wet weight basis) or 3 mol/m^3 (fat weight basis), whereas the water concentration is about 3 ng/L or 9 x 10^{-9} mol/m^3. Fugacities, however, are directly comparable and may be reduced to a range which, at most, extends over 2 orders of magnitude. In terms of fugacity, gull PCB contamination is 2 × 10^{-5} Pa and water contamination is 3 × 10^{-7} Pa. Fugacity thus converts these disparate concentration units into one common unit.

Moreover, the fugacity levels for a persistent chemical in a region appear to fall in a consistent pattern within a relatively narrow range. Thus we can anticipate likely concentrations in one medium from fugacity data for another and develop a predictive capability. This is shown graphically in Figure 4. The biotic components of the environment have a tendency to have the highest fugacities, as shown by fish and by gulls and their eggs.

Several terms are used to describe this phenomenon. The bioconcentration of chemicals usually refers to the uptake of a chemical from water in which equal fugacities for fish and water are approached. Biomagnification refers to a further increase in concentration attributable to uptake from food. It results in a fugacity that may be five times that of the contaminant fugacity in food and water (Figure 3). Bioaccumulation is a broader term that indicates uptake from all sources and thus includes both effects.

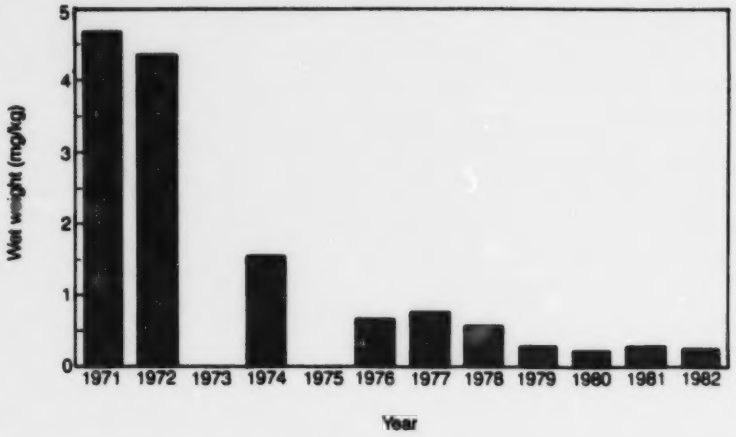
From Figure 4 it is apparent that the gulls show the highest fugacity. Fish also show a high fugacity compared with the physical environment. The generally low fugacity of contaminants in air may be explained by the movement of air from areas of lesser contamination. We are concerned with the chemicals that have a long life in the environment. Short-lived chemicals that are subject to rapid environmental reactions are more often controlled by kinetic factors; these chemicals will have lower fugacities and therefore are generally of less concern.

On the basis of the foregoing, we suggest a framework for analysis and interpretation of environmental- and wildlife-monitoring data. Measured concentrations of contaminants first are converted to fugacities; the fugacities in adjoining media then are compared. In simple situations of rapid exchange, the data should exhibit equifugacity. In other, more complex situations, the fugacities may have fairly constant ratios.

In the case of PCBs, for example, trout may develop a fugacity 15 times that of water and twice that of smelt (Figure 3). These fugacity ratios, which are functions of the chemical itself, also are functions of the nature of the environmental and biological media, but they may be quite constant between localities and they may be relatable to chemical properties.

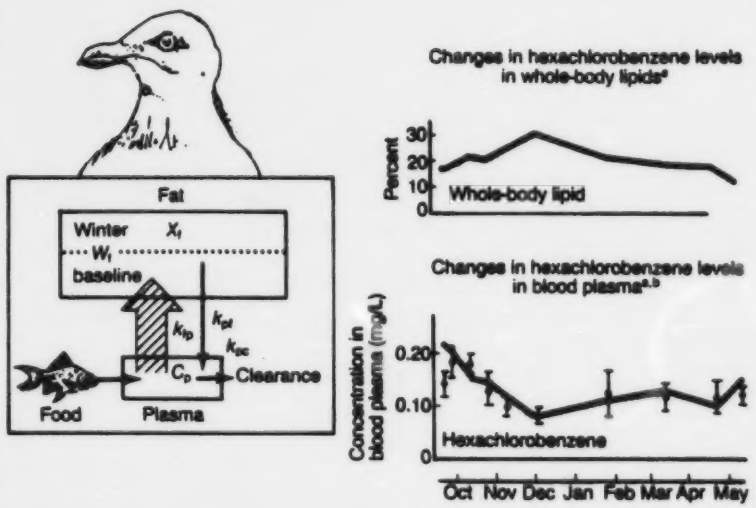
For a chemical that is readily metabolized, such as a polynuclear aromatic hydrocarbon (PAH), the fish's fugacity may be one-tenth to one-hundredth of that of the water (*46*). On the other

FIGURE 5
Hexachlorobenzene residues in herring gull eggs[a]



[a]Eggs were taken from Scotch Bonnet Island, Lake Ontario.

FIGURE 6
Two-compartment model of chemical uptake by herring gulls



[a]Model involves four test animals. Solid line represents model values; shaded area represents standard deviation (SD). Changes are recorded through autumn and winter.
[b]Solid circles in curve for blood plasma represent actual observations (*48*). Error bars in curve for blood plasma represent SD for actual observations (*48*).

hand, wildlife species that lack the enzymes necessary to degrade a specific organic chemical may show elevated fugacities. With the analysis of data sets for many regions it should be possible to explain the entire process of organic chemical transfer from the abiotic environment to wildlife.

The role of toxicokinetics

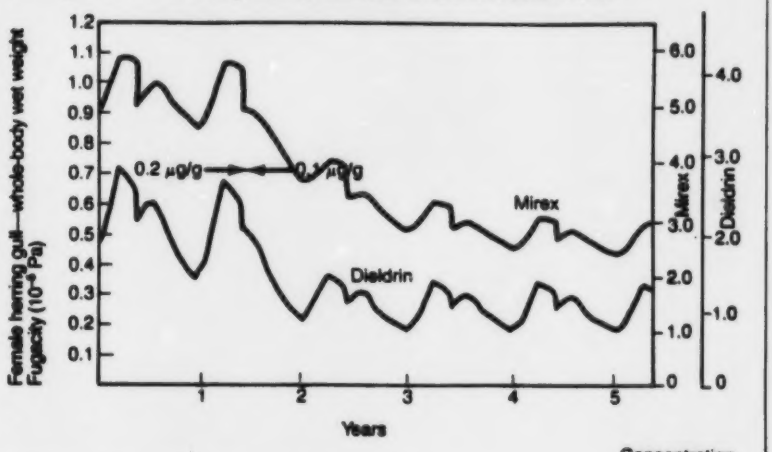
Interpreting these fugacity ratios requires a detailed understanding of the toxicokinetics of chemicals as they migrate through food chains. Such a study is now under way on organochlorine chemicals in herring gulls, smelt, and coho salmon in Lake Ontario (*10, 47*). These monitors have been used by the International Joint Commission; an example of data derived from samples is shown in Figure 5.

The gulls and their eggs are effective monitors. Most of their food comes from aquatic sources. Only the immature birds migrate out of the Great Lakes basin, and adults live to 20 years or more. Gull biology and bioenergetics have been studied extensively (*48*). A relatively simple two-compartment model provides an excellent description of the concentration dynamics as the bird's lipid levels change throughout the year in response to temperature changes (*49*).

To test the validity of the two-compartment model for gulls, a group of birds was injected with a number of organochlorine compounds. Plasma levels then were monitored from autumn to the following spring. Figure 6 shows some experimental data, a fitted curve for one compound (hexachlorobenzene), and a schematic representation of the partitioning of this contaminant between fat and blood plasma through the annual cycle. In practical terms this model allows us to quantify the annual cycle in concentration and fugacity of a contaminant and avoids the pitfalls of comparing winter and summer concentrations.

The model can be used to explore or simulate how a change in environmental contaminant levels or in the food of herring gulls results in a time response toward a new steady-state level for gulls. Figure 7 presents a scenario in which the food levels (concentrations in fish) of dieldrin and mirex, 0.2 mg/kg, rapidly decreased to 0.1 mg/kg. The curves represent free-living females subject to temperature fluctuation and egg laying. Egg laying results in a sharp annual drop in body fugacity as contaminants are cleared via the eggs. The time lag between the change in prey level and the corresponding change in the steady-state level of the monitor species is a function of the rates of metabolism and excretion.

FIGURE 7
Changes in whole-body concentrations of dieldrin and mirex[a]



[a]In gulls, subject to a decrease in the chemicals' concentration in food from 0.2 μg/g to 0.1 μg/g. The effect of egg laying is apparent from the sharp drop in fugacity or concentration in the bird just after the annual peak. The sinusoidal appearance of the curves is caused by the annual lipid fluctuation.

This time lag may be about three years for slow-clearing compounds such as mirex (half life 231 days), compared with less than one year for compounds such as dieldrin (half life 82 days) (*49*).

It is important to determine this time lag because it controls the lag between environmental and tissue concentration changes. The monitored tissue concentration thus is a function of the exposure history over a determinable time period and of the bird's growth, lipid content, and metabolism. It should be possible (and it is a fascinating scientific puzzle) to interpret tissue concentration changes in birds by back-calculating the exposures that caused these levels. This requires a time-dependent toxicokinetic model; indeed, it probably is misleading to interpret wildlife tissue data without such a model.

Assessing human health effects

Fugacity also may play a role in interpreting the nature of extreme contamination events in which wildlife populations were reduced by toxicity. It is possible for gulls to thrive when they obtain food from an aquatic environment contaminated by PCBs at fugacity levels of approximately 10^{-3} Pa. At this level, concentrations of PCBs in water typically are 1 ng/L; in fish, 1 mg/kg; in gull lipids, 30 mg/kg; and in eggs, 10 mg/kg.

If the fugacity is increased by a factor of 10, to 10^{-4} Pa, the concentrations of PCBs increase proportionately and toxic effects become apparent, possibly resulting in population declines. It thus may be possible to determine the fugacities at which populations are adversely affected by each chemical and even by chemicals in combination. The strategy for protecting wildlife then would be to ensure that the chemical's fugacity in the environment is kept below a threshold level at which adverse effects are manifest. Laboratory experiments may be used to help establish these levels.

With this approach, it may be possible to establish a dose–response relationship for a population of wildlife existing within a defined ecosystem. Wildlife can be protected from excessive contamination, and hence danger. It is noteworthy that we humans also occupy a place within these ecosystems and are subject to the same dangers.

In the design of monitoring programs, it is important to allocate resources for analyzing the findings in terms of the contaminant status throughout the entire biotic and abiotic environment. Fugacity provides a convenient tool for such analyses and helps to integrate disparate environmental monitoring efforts. We believe that such syntheses are a fruitful area for research.

Viewed from this perspective, wildlife takes on an enhanced value as a component of the overall environmental monitoring and surveillance effort. We can identify vulnerable species for each chemical in each region. We can observe their condition, periodically analyze their tissues, and confirm that levels (fugacities) of chemical contamination are being maintained below certain targets. Trends can be established and early warning can be obtained about increases that ultimately may affect wildlife populations and human

health. This is essentially a reiteration of the opinion frequently expressed by wildlife enthusiasts that the best guarantee of continued human health is to maintain an environment in which wildlife will flourish.

It is now possible to use environmental and toxicokinetic models to establish quantitative links between emissions, abiotic concentrations, concentrations in wildlife, and ecological viability. The disparate scientific efforts of environmental modeling, toxicology, toxicokinetics, and fundamental wildlife biology and ecology thus become mutually supportive and can contribute to a rational strategy for ensuring that we create and maintain a healthful environment.

Acknowledgments

This work was supported by the Wildlife Toxicology Fund of Environment Canada, the Ontario Ministry of the Environment, and the Natural Sciences and Engineering Research Council. We thank H. Won, C. Weseloh, J. Elliott, P. Angehrn and Y. Ouellette. A. J. Keith and P. G. Wells provided helpful comments.

This article was reviewed for suitability as an *ES&T* feature by Ronald J. Kendall, Western Washington University, Bellingham, Wash. 98255; and by Yoram Cohen, University of California, Los Angeles, Los Angeles, Calif. 90024.

References

(1) Ratcliffe, D. A. J. Appl. Ecol. 1970, 7, 67–116.
(2) Risebrough, R. W.; Teeple, S. M.; Gilbertson, M. *Can. J. Zool.* **1983**, *61*, 427–36.
(3) Blus, L. J. et al. *Nature* **1972**, *240*, 164–66.
(4) Spitzer, R. R. et al. *Science* **1978**, *202*, 333–35.
(5) Gilbertson, M. R.; Fox, G. A. *Environ. Pollut.* **1977**, *12*, 211–16.
(6) Norstrom, R. J.; Gilman, A. P.; Hallett, D. J. *Sci. Total Environ.* **1981**, *20*, 217–30.
(7) Kendall, R. J. *Environ. Sci. Technol.* **1982**, 16, 448A–453A.
(8) Wren, C. D. *Environ. Monit. and Assessment* **1986**, *6*, 127–44.
(9) Goldberg, E. D., *Environ. Monit. and Assessment.* **1986**, *7*, 91–103.
(10) Mineau, P. et al. In *Toxic Contaminants in the Great Lakes;* Nriagu, J. O.; Simmons, M. S., Eds.; Wiley: New York, 1984; pp. 425–52.
(11) Phillips, D. J. *Quantitative Aquatic Biological Indicators;* Applied Science Publishers: London, 1980.
(12) Cohen, Y. C. In *Pollutants in a Multimedia Environment;* Cohen, Y. C., Ed.; Plenum: New York; 1986; pp. 7–48.
(13) *J. Great Lakes Res.* **1987**, *13*, 387–96.
(14) Thomann, R. V.; DiToro, D. M. *J. Great Lakes Res.* **1983**, *9*, 474–96.
(15) Mackay, D.; Paterson, S. *Environ. Sci. Technol.* **1982**, *16*, 654A.
(16) Paterson, S.; Mackay, D. In *The Handbook of Environmental Chemistry;* Hutzinger, O., Ed.; Springer-Verlag: Heidelberg, 1985; Vol. 2, Part C, pp. 121–40.
(17) Mackay, D. et al. *Chemosphere* **1985**, *14*, 335–74.
(18) Connolly, J. P., Pedersen, C. J. *Environ. Sci. Technol.*, in press.
(19) Braune, B. et al. "Dynamics of Organochlorine Substances in Herring Gulls: III. Tissue distribution of PCB congeners, PCDD's, DDE, HCB, Mirex and Cyclodiene compounds in Lake Ontario"; Technical Report; National Wildlife Research Center, Canadian Wildlife Service, Ottawa, 1987.
(20) Strachan, W.M.J.; Edwards, C. J. In *Toxic Contaminants in the Great Lakes;* Nriagu, J. O.; Simmons, M. S., Eds.; Wiley: New York, 1984; pp. 239–64.
(21) Biberhofer, J.; Stevens, R.J.J. "Organochlorine Contaminants in Ambient Waters of Lake Ontario"; Inland Waters Directorate, Scientific Series Bulletin 159; Inland Waters Directorate: Ottawa, Ontario, Canada, 1987.
(22) Eisenreich, S. J.; Looney, B. L.; Thornton, J. D. *Environ. Sci. Technol.* **1981**, *15*, 30.
(23) Oliver, B. G.; Nicol, K. D. *Sci. Total Environ.* **1984**, *39*, 57–70.
(24) Scrudato, R. J.; Del Prete, A. J. *Great Lakes Res.* **1982**, *8*, 695–99.
(25) Mackay, D.; Paterson, S. *Environ. Sci. Technol.* **1984**, *18*, 207A–214A.
(26) Oliver, B. G.; Charlton, M. N. *Environ. Sci. Technol.* **1984**, *18*, 903–8.
(27) McCrea, R. C.; Fischer, J. D.; Kuntz, K. W. *Water Poll. Res. J. Canada* **1985**, *20*, 67–78.
(28) Kauss, P. B.; Suns, K.; Johnson, A. F. In *Physical Behavior of PCBs in the Great Lakes;* Mackay, D. et al., Eds.; Ann Arbor Science: Ann Arbor, Mich., 1983; pp. 385–410.
(29) Yin, C.-Q. Ph.D. Dissertation, State University of New York, Syracuse, 1985.
(30) Miller, M. M. et al. *Environ. Sci. Technol.* **1985**, *19*, 522–29.
(31) Melinikov, N. N. *Residue Rev.* **1971**, *36*, 68–69.
(32) Weast, R. C. In *Handbook of Chemistry and Physics*, 53rd ed.; CRC Press: Boca Raton, Fla., 1973.
(33) Veith, G. D.; Defoe, D. L.; Bergstedt, B. G. *J. Fish. Res. Board Can.* **1979**, *36*, 1040–48.
(34) Neely, W. B.; Branson, D. R.; Blau, G. E. *Environ. Sci. Technol.* **1974**, *8*, 1113–15.
(35) Smith, J. H. et al. "Environmental Pathways of Selected Chemicals in Freshwater Systems, Part II: Laboratory Studies"; EPA Report 600/7-78-074; EPA: Washington, D.C., 1978.
(36) In *Handbook of Environmental Data on Organic Chemicals*, 2nd ed.; Verschueren, K., Ed.; Van Nostrand Reinhold: Toronto, 1983; pp. 432, 434, 437, 513.
(37) Gunther, F. A.; Westlake, W. E.; Jaglan, P. S. *Residue Rev.* **1968**, *20*, 1.
(38) Weil, L.; Dure, G.; Quantin, K.E.Z. *Wasser Abwasser Forsch.* **1974**, *7*, 169.
(39) Triggan, J. W.; Dutt, G. R.; Riggs, R. L. *Bull. Environ. Contam. Toxicol.* **1967**, *2*, 90.
(40) Edwards, C. A. *Residue Rev.* **1966**, *13*, 83.
(41) Spencer, W. F. *Residue Rev.* **1975**, *59*, 91–117.
(42) Harris, C. R.; Mazurek, J. H. *J. Econ. Entomol.* **1964**, *57*, 698.
(43) Zimmerli, B.; Marek, B. *Mitt. Geb. Lebensmitteluniters Hyg.* **1974**, *65*, 55.
(44) Briggs, G. C. *J. Agric. Food Chem.* **1981**, *29*, 1050–59.
(45) Mackay, D. et al. In *Physical Behavior of PCBs in the Great Lakes;* Mackay, D. et al., Eds.; Ann Arbor Science: Ann Arbor, Mich., 1983; pp. 59–70.
(46) Southworth, G. R.; Keffer C. C.; Beauchamp, J. J. *Environ. Sci. Technol.* **1980**, *14*, 1529–31.
(47) Norstrom, R. J.; Hallett, D. J.; Sonstegard, R. A. *J. Fish. Res. Board Can.* **1978**, *35*, 1401–9.
(48) Norstrom, R. J. et al. *Ardea* **1986**, 74, 1–23.
(49) Clark, T. P. et al. *Environ. Toxicol. Chem.* **1987**, *6*, 547–59.

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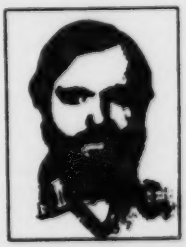

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Ross J. Norstrom *(r) is chief of chemistry research at the National Wildlife Research Center of Environment Canada in Hull, Quebec. His areas of expertise include the modeling, pharmacodynamics, bioaccumulation, and analysis of organochlorine environmental contaminants in fish and birds.*

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Ottawa Citizen, Ont.
(...) 137,939
Novemb[illegible] 2, 1987
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Toxic pesticides threaten wildlife, researcher says

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And as these residues erode the foundations of the environment, politicians and scientists are doing little to either comprehend or combat them, said Monte Hummel, president of the World Wildlife Fund Canada.

Insect and weed killers along with various industrial chemicals are polluting the entire planet, from industrial centres to such remote areas as the Arctic, he said.

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Although governments in Canada and the United States have controlled a number of pollutants such as the pesticide DDT, Canada's wildlife is still being affected by such chemicals.

Some North American companies produce chemicals which do not meet domestic standards and sell them in Latin America.

While wintering in the south, such migratory birds as peregrine falcons receive enough pesticide poisoning to damage their reproductive abilities.

For years, scientists have detected the chemicals in polar bears and birds in the deep wilderness.

But the most serious threat is posed from chemical attacks on micro-organisms that control such building blocks of life as soil fertility and air quality.

Losses at this level would be "like losing bricks at the foundation of your house," he said.

investigating officials suspect that the carbon filter may have gradually accumulated traces. Another possibility is a reaction involving chlorine and a second chemical; even the filter itself is being examined as an original source of dioxin. This much is certain: for the first time in North America, traces of toxic dioxin have been identified in a water-treatment filter. And as filtration systems grow more sophisticated (Pollution Probe, for example, has long pushed for the extensive use of GAC filters), the unsavoury content of our water supply will increasingly reveal itself.

Larry Scanlan

POLLUTION GONE WILD

A general alarm is sounding across the country as the latest results from research into the effects of toxins on wildlife species ranging from burrowing owls to caribou come to light. The second annual report of the Wildlife Toxicology Fund, a research partnership formed between Environment Canada, World Wildlife Fund Canada and Noranda Inc., shows that almost all of the 42 projects it has supported since 1985 are yielding grim results. No longer, it suggests, are chemical problems confined to urban industrial areas. "Toxic chemicals," says Pegi Dover, secretary to the Wildlife Toxicology Fund, "are having an impact right across the board."

In Hamilton Harbour and in Cranberry Marsh, near Whitby, Ontario, toxicology researcher Ronald Brooks has found that high heavy-metal levels in snapping turtle eggs are reducing its population and causing deformities in hatchlings. In Wood Buffalo National Park, straddling the border of Alberta and the Northwest Territories, researcher Josef Svoboda has discovered caribou contaminated by radiation fallout from the Chernobyl disaster. And in Clyde, Alberta, 40 miles (65 km) north of Edmonton, zoologist David Boag has determined that a grasshopper insecticide called carbofuran so effectively knocks out freshwater amphipod populations that dabbling ducks in the area are left with very little to feed on.

Once common in southern Saskatchewan, burrowing owls are being knocked out by a grasshopper insecticide called carbofuran.

Similarly, another study, independent of the World Toxicology Fund, has revealed that the use of grasshopper insecticides in Saskatchewan is reducing the population of the burrowing owl, once a common bird in pastures of southern Saskatchewan and around Saskatoon. Its current Canadian number is estimated at only 1,800 pairs. "Farmers are wondering where they've gone," says Paul James, curator of ornithology at the Saskatchewan Museum of Natural History.

In 1986, a year now famous for its prairie grasshopper plagues, James set out to discover how the insecticides were affecting the owls. He concludes that when carbofuran is sprayed within 165 feet (50 m) of the owls' nests, offspring are reduced by up to 54 percent. The use of alternative sprays, however, has less dramatic effects. Carbaryl sprayed within the same distance, for example, reduces offspring by 13 percent.

While James acknowledges that his research is unlikely to halt the use of chemicals, especially by farmers faced with ravaging grasshoppers, he says he is encouraged by the fact that many farmers within his test area have now stopped using carbofuran.

Carolyn Fleming

THE PIKE THAT HIKED

When an angler caught a northern pike in British Columbia's Summit Lake last summer, it was a harbinger of problems to come for provincial fisheries officials.

One of the leading sport fish in Canada, pike, also called jackfish, are a long way from home in the waters 30 miles (50 km) north of Prince George, and their relocation "could lead to disaster," says Dennis Ableson, a biologist with the Recreational Fisheries Branch.

An interloping pike has caused alarm among B.C. biologists

The problems with pike are threefold: being voracious predators, they consume enormous quantities of other fish; they outbreed less prolific fish like trout and salmon; and they often carry a three-stage parasitic tapeworm called *Triaenophorous crassus*. In its second stage, the parasite may be eaten by salmonids, which then develop unsightly cysts. "It is not harmful to humans," says Ableson, "but nobody would purchase or eat a fish with these ugly sores."

The pike in the Summit Lake/Crooked River watershed are dangerously close to the Fraser River system. "Something as simple as a beaver dam or a mud slide that raises the water could divert pike into the Fraser," says Ableson. "The economic implications of the parasite getting into trout and salmon populations are very serious."

Serious, indeed. The one pike caught in Summit Lake prompted the B.C. Ministry of Environment and Parks and the federal Department of Fisheries and Oceans to take immediate action. In August and September, they spent more than 1,000 hours using varying sizes of gill nets to catch around 15,000 fish; only one adult pike was found – a 6½-pound male (3 kg) that showed no trace of the parasite. "But our testing indicates it had spawned, which heightens our fear that it may have spawned in Summit Lake," says Gerry Taylor, a manager

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CANADIAN PRESS CLIPPING SERVICES
A2/ THE TORONTO STAR, TUESDAY, NOVEMBER 3, 1987

Toxic chemicals threaten wildlife, report says

By David Israelson Toronto Star

Canada's wildlife is being poisoned by toxic chemicals, a new report to the federal government says.

"The poisons can be found in species ranging from the smallest aquatic insect to the polar bear," says the World Wildlife Fund, which co-ordinated a $5.3 million research program for the government.

The toxic chemicals "pose a growing threat," says the report on the two-year-old program, called the Wildlife Toxicology Fund.

The report, which documents ongoing scientific work, says:

- Toxic pollution is believed responsible for tumors in Lake Ontario fish, metal contamination in moose and deer, scarce food for prairie ducks and snapping turtle eggs that have trouble surviving;
- The pollution is mounting a three-front attack, on land, water and from the air — sometimes all at once. Acid rain, for example, is believed to be leaching toxic metals from the soil, and the metals are then absorbed by sugar maples, causing them to weaken or die;
- The chemicals come from many countries, end up almost everywhere and are certainly "not confined to the country's urban, industrialized pockets."

In the North, for example, "caribou are feeding on lichen contaminated with radiation from the Chernobyl (nuclear) incident," the report says.

And pesticides spread over farmlands and forests "have caused egg-shell thinning for peregrine falcons in the Northwest Territories."

The program paid for 42 projects, with half of the money coming from the environment department and half from the private sector, provincial governments and other federal departments.

It was put together by the World Wildlife Fund, whose patron is Prince Philip, to replace a federal research program that was cut by the Progressive Conservative government in 1984.

The budget cut was strongly criticized by environmentalists and scientists, who said it was important to continue studying how pollution affects wildlife.

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Toxic pesticide residue worries wildlife researcher

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And as these residues erode the foundations of the environment, politicians and scientists are doing little to comprehend or combat them, said [illegible] Hummel, president of World Wildlife Fund Canada.

Insect and weed killers along with various industrial chemicals are polluting the entire planet, from industrial centres to such remote areas as the Arctic, he said.

"You cannot run away from it."

Hummel's comments came during the release of the report of the Wildlife Toxicology Fund.

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Financial Post
Toronto, Ontario
November 16, 1987
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Economic and environmental issues merge

By Monte Hummel

THE RECENT REPORT of the National Task Force on Environment and Economy offers an excellent starting point for redefining the relationship between Canada's environment and its economy.

Clearly, the old adversarial stances are no longer appropriate. As the report confirms, "Environmental conservation and economic development not only can exist, they must co-exist, for one is a condition of another."

The reality of that message has been more evident perhaps in countries of the Third World. Bilateral and multilateral aid assistance offered in the name of economic development has all too often been accompanied by disastrous environmental *and* economic consequences. In many cases, rampant logging and massive hydro-electric schemes have wiped out local sustainable resources. Economic gains have been short-term, as logged land has proved unproductive for farming and rivers have become choked with eroded soil.

In Canada, the linkage between the environment and the economy is becoming increasingly clear. The decline of the Great Lakes' commercial fishery due to pollution; the gap between deforestation and reforestation, which threatens the long-term viability of Canada's No. 1 industry, and the air pollution and acid rain which threaten the maple syrup industry, tourism and sport fishing in central Ontario, are only a few examples.

Sparked by the May, 1986, visit of the World Commission on Environment and Development, the task force has adapted the concept of sustainable economic development — using resources and the environment in a way that does not damage prospects for their use by future generations — to the Canadian context.

The report specifically calls for: government, industry and nongovernmental organizations (NGOs) to develop tripartite programs; specific projects to demonstrate environment-economy integration; industry associations to endorse environmental assessment as an integral part of the decision-making process; and the establishment of provincial Round Tables on environment and economy.

That the task force membership was drawn from the top echelons of industry, government and NGOs offers hope that the report is only the first step. We must now breathe life into the recommendations.

One specific initiative may provide a model for the kind of industry/government/NGO cooperation advocated in the report. The Wildlife Toxicology Fund (WTF), established by the World Wildlife Fund in 1985 to support high-calibre research on the effects of toxic chemicals on wildlife, is an innovative and hitherto unlikely partnership. Environment Canada has provided $3 million in core funding over three years. Noranda Inc. has contributed $140,000 toward administrative costs, along with Esso Resources, Polysar and Inco. Administrative responsibility rests with World Wildlife Fund.

To date, 42 research projects have been supported at 21 institutions across the country. Because funds are awarded on a matching basis, $5.3-million worth of wildlife toxicology research is currently under way as a result of Environment Canada's investment. Matching funds have been provided by the private sector, as well as provincial governments, federal departments, and even Argentina's government.

By stretching scarce government dollars and securing the moral and financial support of a number of corporate partners, the WTF is successfully addressing an environmental issue of growing concern in Canada. Applied research in such areas as the effects of dioxin on herring gulls, grasshopper spraying on Prairie wildlife, petroleum oil on seabirds, and cadmium in moose and deer is providing the groundwork for remedial action. The results will be channelled to those environmental and economic decision-makers involved in the management of toxic chemicals.

Perhaps this kind of partnership should be applied to a number of environmental issues. The national task force has provided Canada with the leadership to begin to integrate environmental and economic concerns. The momentum must not be wasted. What better rallying cry than that of Susan Holtz, a task force member: "Let's treat Canada as if we plan to stay."

MONTE HUMMEL *is president of World Wildlife Fund Canada.*

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November 2, 1987
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Toxic pesticides threaten wildlife, researcher says

J-9107

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It was created after large cuts in toxic chemical research by the federal government in 1984, but now only provides enough money to study "the tip of the iceberg," Hummel said.

For years, all levels of government have been reluctant to face the seriousness of chemical pollution, he said.

One environment minister after another, "dearly hopes they are not the one who is going to have to tell it like it is and commit the amounts of money necessary" to correct the situation, he said.

Although governments in Canada and the United States have controlled a number of pollutants such as the pesticide DDT, Canada's wildlife is still being affected by such chemicals.

Some North American companies produce chemicals which do not meet domestic standards and sell them in Latin America.

While wintering in the south, such migratory birds as peregrine falcons receive enough pesticide poisoning to damage their reproductive abilities.

For years, scientists have detected the chemicals in polar bears and birds in the deep wilderness.

But the most serious threat is posed from chemical attacks on micro-organisms that control such building blocks of life as soil fertility and air quality.

Losses at this level would be "like losing bricks at the foundation of your house," he said.

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Toxic pesticide residues seen threat to wildlife

TORONTO (CP) — Canada is being blanketed by a layer of toxic pesticide residues that are threatening the country's animal life, a senior wildlife researcher said Friday.

And as these residues erode the foundations of the environment, politicians and scientists are doing little to either comprehend or combat them, said Monte Hummel, president of the World Wildlife Fund Canada.

Insect and weed killers along with various industrial chemicals are polluting the entire planet, from industrial centres to such remote areas as the Arctic, he said.

"You cannot run away from it."

Hummel's comments came during the release of the report of the Wildlife Toxicology Fund.

The World Wildlife Fund operates the program with funding from Environment Canada, provincial governments and industry.

It was created after large cuts in toxic chemical research by the federal government in 1984, but now only provides enough money to study "the tip of the iceberg," Hummel said.

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4601 YONGE ST.,
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Toronto Globe & Mail, Can.
Circ. 319,162
October 31, 1987

CANADIAN PRESS CLIPPING SERVICES

Blanket of pesticides called threat

BY MICHAEL KEATING
The Globe and Mail

J-102

Canada is being blanketed by "a thin film of pesticide residues" that is contributing to the decline of animal life, a senior wildlife researcher said yesterday.

Insect and weed killers along with a host of industrial chemicals are spreading to such a degree that they are polluting the whole biosphere of the planet said Monte Hummel, president of World Wildlife Fund Canada.

"You cannot run away from it," Mr. Hummel said. Chemicals are found not only downwind from industrial centres but in remote areas such as the Arctic.

For years scientists have found industrial chemicals in polar bears and birds in the deep wilderness.

But Mr. Hummel said he believes there is a more serious threat from chemical attacks on life at the microscopic level but few scientists are studying the problem.

Micro-organisms in the soil control such building blocks of life as the fertility of soil and the breathability of the air.

If chemical pollutants are attacking this level of life, as some scientists have suggested, "then we are in real trouble," Mr. Hummel said. He said losses at this level would be "like losing bricks at the foundation of your house."

Mr. Hummel made his comments while releasing a report of the Wildlife Toxicology Fund, a program World Wildlife Fund runs with money from Environment Canada, provincial governments and industry.

The fund was created after the big toxic chemical research cuts of the federal Government in 1984 but only provides enough money to study "the tip of the iceberg," Mr. Hummel said.

He said that for years governments at all levels have been reluctant to face the seriousness of chemical pollution.

One environment minister after another, "dearly hopes they are not the one who is going to have to tell it like it is and commit the amounts of money necessary" to correct the situation.

Mr. Hummel said that although Canada and the United States have controlled a number of nasty pollutants such as the pesticide DDT, wildlife in Canada is still being affected by such chemicals.

He said that some North American companies make chemicals which do not meet domestic standards and sell them in Latin America. As a result migratory birds like peregrine falcons get enough pesticide poisoning while wintering in the south to endanger their ability to reproduce.

Canada still uses enough hazardous chemicals to make such areas as the Prairies and forests "pesticidal sinks" which threaten the health of wildlife, Mr. Hummel added.

1. "Bioassays for the Toxicity of Petroleum Oils to Sea Birds"

Co-ordinator:

Dr. Frederick Leighton
Dept. of Veterinary Anatomy
University of Saskatchewan

Description:

The project is determining if bioassays can be developed and substituted for live animal experiments to assess the potential systemic toxicity of petroleum oils to birds. Currently, differences in potential systemic toxicity are not considered in environmental impact assessments or in planning marine exploration, production or transport of petroleum oils.

Two biological systems are being developed for possible use in bioassay systems: Red blood cells exposed to petroleum oils in vitro and chicken embryos exposed by contamination of the egg shell surface. To date, the red blood cell bioassay has been problematic. Several of the biochemical measures of toxicity described in in vivo work have proved to be unusable due to the physical presence of petroleum oils or other essential reagents in the in vitro preparation. The most appropriate measure for this bioassay appears to be formation of Heinz bodies. Work on the avian embryo bioassay has determined that the chicken embryo, 7 - 9 days of age, is highly sensitive to the toxic effects of petroleum oils

Funding:

The WTF approved a grant of $108,200 with $31,000 payable in 1985/86, $26,000 payable in 1986/87 and $51,000 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from the federal Department of Energy, Mines and Resources, the Medical Research Council and the University of Saskatchewan.

2. "Potential Transfer of Metals from Lakes to Mammals, Birds and Reptiles"

Co-ordinator:

Dr. Harold Harvey
Dept. of Zoology
University of Toronto

Description:

The project is examining the impact on wildlife of metals mobilized by acid rain. Using lakes in the Muskoka-Haliburton area of Ontario, Dr. Harvey and Ms. Leah Bendell-Young are investigating the transfer of metals from the aquatic environment, water and sediment, into food organisms, chironomids and crayfish, to vertebrates such as reptiles, mammals and birds. The transfer of metals is being studied in relation to two key factors --- lake depth and acidity.

Included among the results is the finding that average concentrations of zinc were lower, whereas concentrations of cadmium were up to a magnitude greater in the gills of crayfish from acidic versus non-acidic lakes. In addition, zinc and copper levels in the muscle of crayfish correlate positively with increasing crayfish size.

It was also shown that the accumulation of metals such as Zn, Cd and Cu by fish sampled from lakes spanning a range of pH levels was not simply related to change in availability associated with changes in lake pH. Rather, metal accumulation by fish was influenced by several biotic and abictic factors, complicating their use as a bioassays for purposes of environmental monitoring.

Funding:

The WTF approved a grant of $52,451 for the project with $28,300 payable in 1985/86 and $24,151 payable in 1986/87.

Matching Funds:

The Ontario Ministry of the Environment and the Ontario Ministry of Natural Resources have provided matching funds for the project.

3. "Fluorosis in American Kestrels"

Co-ordinator:

Dr. David Bird
Macdonald College Raptor Research Centre
McGill University

Description:

Industrial activity has dramatically increased the flow of fluoride contaminants through the ecosystem. While extensive research has been conducted on the effects of fluoride on domestic animals, little is known of the movement of this chemical through a predator-prey system and the extent of fluoride-induced injury to wild birds.

Dr. Bird's research is seeking to determine the impact of environmental fluoride on the survivorship and reproductive success of wild Kestrels. Through an assimilation study, the solubility of aluminum fluoride is being assessed and its physiological impact on Kestrels measured. In addition, by comparing the assimilation rates of aluminum fluoride and sodium fluoride, Dr. Bird is measuring the differing impacts of the two fluorides on American Kestrels.

Funding:

The WTF approved a grant of $19,820 for the project.

Matching Funds:

The Natural Sciences and Engineering Research Council (NSERC) and the Quebec Department of Leisure, Fish and Game have provided the matching funds for the research.

4. "Speciation of Lead in Soft Tissues of Pigeons from Four Sites in Metropolitan Montreal and Environs"

Co-ordinator:

Dr. W.D. Marshall
Dept. of Food Sciences & Agricultural Chemistry
Macdonald College, McGill University

Description:

Burdens of ionic alkylleads in soft tissues of pigeons from three urban colonies in metropolitan Montreal were compared with burdens in the same tissues from one suburban/rural colony. Whereas triethyllead was ubiquitous in liver and kidney samples from each of the colonies, trimethyllead was observed only in kidney samples from two of the urban colonies. The burdens of triethyllead in kidney samples paralleled vehicular traffic patterns in the vicinity of the colony.

The spectrum of alkylleads in pigeons was quite different from the spectrum of alkylleads observed in earlier studies with Mallard Ducks and Herring Gulls in which methyllead salts were the major toxicants. It is postulated that an environmentally mediated methylation of Pb^{2+}, which is more active in aquatic environments, accounts for increased levels of methylleads (relative to ethylleads) in gulls and ducks.

Funding:

The WTF approved a grant of $36,715 for this project.

Matching Funds:

Matching funds were received from NSERC.

5. "Mechanisms of Metal Cycling Between Aquatic Insects and Terrestrial Wildlife"

Co-ordinator:

Dr. Pamela Stokes
Institute for Environmental Studies
University of Toronto

Description:

The bioaccumulation of toxic materials by components of the food chain is an important arena of research in environmental sciences. Dr. Stokes has undertaken an investigation of the mechanisms by which larval insects accumulate metals from sediments and pass them on to terrestrial wildlife. The research is one component of a larger study on metal mobilization and transport in metal contaminated or acidified systems.

Among other results, the study has revealed that chironomid larvae from a contaminated site contain several metals (e.g. Al, Cu, Ni, Pb) in specific body regions more frequently than in other body regions and more frequently than in larvae from a less contaminated site. The data suggest that some metals may be stored by larvae and enter the food web differently under varying levels of pollution.

Funding:

The WTF approved a grant of $8,100 for the project. The entire grant was paid in 1985/86.

Matching Funds:

Matching funds for the project were secured from NSERC and from the Institute for Environmental Studies.

6. "Contaminant Impacts Assessed by the Biomass Size Spectrum"

Co-ordinator:

Dr. G. Sprules,
Dept. of Zoology
University of Toronto

Description:

In this project, the effects of cresol on continuous cultures of bacteria and their protozoan predators are being assessed using the biomass size spectrum. The biomass size spectrum, which characterizes organisms by body size to provide insights into the structure and functioning of lakes and oceans, is a promising new model of ecosystem structure. Its value lies in its focus on toxic effects on whole communities, rather than just on single species.

Results to date indicate that cresol adversely affects the growth of protozoan Colpidium campylum at doses of 100 mg/L. The development of new computer software facilitating fast sorting of data into 40 species categories has allowed for the direct matching of community size patterns with those of component species. Communities living in continuous-flow (open) systems and those confined to batch (closed) systems show relatively smooth and bumpy size spectra respectively.

Funding:

The WTF approved a grant of $73,791 for the project, with $25,515 payable in 1985/86, $23,263 payable in 1986/87 and $25,013 payable in 1987/88.

Matching Funds:

Matching funds for the project have been secured from NSERC and the Institute for Environmental Studies.

7. "Effects of PCP on Gammarus Tigrinus"

Co-ordinator:

Dr. F. Baerlocher
Dept. of Biology
Mount Allison University, Sackville, N.B.

Description:

Pentachlorophenol (PCP) is widely used to treat wood and wood products against fungal decay. Today, levels of PCP in freshwater streams range from trace amounts to 100 ppm. Its toxic effect is not restricted to fungi, and it acts as a broad spectrum biocide. PCP accumulates in lipid tissues and is therefore often concentrated in successive trophic levels.

The project was designed to study PCP accumulation in a widespread amphipod, Gammarus tigrinus, and assess how this animal is affected in its survival, growth efficiency, and tolerance of environmental fluctuations by exposure to PCP.

Experiments revealed that Gammarus tigrinus is moderately affected by PCP contamination in the short term and that low, sublethal concentrations can have serious consequences to the animal in the long term. Its ability to accumulate reserves is weakened, which lowers its ability to maintain populations under stressful conditions. Due to its significance as a link in a food web, higher trophic levels will suffer as well.

Funding:

The WTF approved a grant of $15,000. The entire grant was paid in 1985/86.

Matching Funds:

Matching funds for the project were received from NSERC.

8. "Biological Significance of Trace Metals in Sediments"

Co-ordinator:

Dr. Andre Tessier
Institut National de la Recherche Scientifique
University of Quebec

Description:

In Canada, mining and smelting activities, dredging and disposal operations and lake acidification are areas of concern with respect to trace metal contamination of the aquatic environment. A major portion of the trace metals introduced into the aquatic environment is found associated with bottom sediments, where they constitute a potential danger to benthic organisms. Simple relationships between trace metal concentrations in such organisms and total metal concentrations in adjacent sediments are seldom found.

Through his research, Dr. Tessier is seeking to identify the key biotic and abiotic factors involved in the accumulation of trace metals by representative organisms. The time response of metal body burdens in bivalves to changes in environmental conditions is also being studied. To date, the research indicates: 1) an increase in cadmium concentration in organisms transferred from a relatively unpolluted lake to a lake polluted with trace metals; 2) small seasonal variation in metal concentrations for the indigenous organisms in the two lakes; 3) increase in metal concentrations for the organisms transferred from the less polluted lake to the more polluted lake and 4) decrease in the metal concentrations in the organisms transferred from the more polluted lake to the less polluted lake.

Funding:

The WTF approved a gant of $90,000, with three annual instalments of $30,000 each.

Matching Funds:

Matching funds for the project have been received from NSERC, the Institut National de la Recherche Scientifique and the Quebec government's Ministry of Education.

9. "Hydrocarbon & Organohalogen Pollutants in a Shorebird Food Resource"

Co-ordinator:

Dr. R. G. Ackman
Technical University of Nova Scotia

Description:

Four out of five species of migrating shore birds in the Minas Basin area of Nova Scotia feed almost exclusively on the mud-dwelling amphipod Corophium Volutator. The safety of this geographically specific food resource for migrating shorebirds has not been investigated in depth for hydrocarbons and organohalogens, the major pollutant class associated with lipids and potentially toxic to such birds.

With WTF support, Dr. Ackman has examined the role of the amphipod in accumulating hydrocarbons and organohalogen materials and transferring these compounds to the fats of shorebirds staging through the upper Bay of Fundy area. The results reveal an absence of these contaminants. Dr. Ackman suggests that there is no fat body in the amphipod, such as the oil sac common in pelagic copepods, where hydrocarbons from the diet would dissolve into bulk neutral lipids. The absence of chlorinated hydrocarbons follows from the same lack of lipid storage material.

Funding:

The WTF approved a grant of $3,500 for the project.

Matching Funds:

The National Research Council of Argentina has provided the matching funds for the project.

10. "Levels of Toxic Chemicals in Selected Birds in Manitoba"

Co-ordinator:

Dr. Merlin Shoesmith
Natural Resources Institute
University of Manitoba

Description:

Elevated levels of toxic pollutants have contributed to decreased reproductive success and population declines among several species of hawks, owls, and fish-eating birds which are near the top of the terrestrial and aquatic food chains. In Manitoba, populations of several colonial nesting birds and raptors are in decline. High level of pollutant residues have been recorded in some of these species, but data from others that are in decline or from different geographical areas are lacking.

Dr. Shoesmith and his research team are monitoring mercury, PCBs and other organochlorines in a number of Manitoba bird species, including the Great Horned Owl, the Red-necked Grebe, the Great Blue Heron and the Double-crested Cormorant. Tissue samples from bird carcasses and eggs are being collected from veterinarians, taxidermists, commercial fishermen and field researchers. Initial results for Great Horned Owls indicate elevated levels of mercury and DDE, although not likely high enough to result in mortality or reproductive problems. Piscivorous species such as the Red-breasted Merganser, Hooded Merganser and Common Tern had mercury concentrations exceeding 0.35 ug/g, whereas the more omnivorous gulls and grebes had concentrations ranging from .06 to.28 ug/g.

Funding:

The WTF approved a grant of $59,293, with $12,500 payable in 1985/86, $28,793 payable in 1986/87 and $18,000 payable in 1987/88.

Matching Funds:

Matching funds have been secured from the Government of Manitoba.

11. "Study of the Effects of Toxic Metal Pollutants on a Cellular System Pertinent to Aquatic Wildlife"

Co-ordinator:

Dr. Francine Denizeau
Department of Chemistry
University of Quebec at Montreal

Description:

Currently, little information exists concerning the combined toxicity of metals. In her research, Dr. Denizeau is attempting to determine the presence of synergistic and antagonistic interactions among cadmium, copper and mercury. To this end, cells derived from the liver tissue of rainbow trout are being isolated and exposed to these metals. Detection of disturbing effects is being accomplished using indicators of cytotoxicity and genotoxicity.

To date, the results indicate that some heavy metal combinations can give rise to cytotoxic interactions in trout liver cells. Using amino acid incorporation into proteins as indicator of cytotoxicity, it was found that the effects of mixtures of Cd and Hg were greater than those which could be anticipated from individual treatments. In contrast, the Cd/Cu pair did not produce any detectable interaction under the conditions of the experiment. The research is also helping demonstrate the utility of *in vitro* tools for toxicological evaluation. With cell culture systems, careful control of experimental conditions is possible and biochemical parameters can be monitored with relative ease.

Funding:

The WTF approved a grant of $50,000, with $11,000 payable in 1985/86, $25,000 payable in 1986/87, and $13,500 payable in 1987/88.

Matching Funds:

Matching funds for the project have been secured from the University of Quebec at Montreal.

12. "The Significance of Neoplasia in Wild Fish Populations"

Co-ordinator:

Dr. Michael Hayes
Dept. of Pathology
University of Guelph

Description:

The use of wild fish as biological monitors for carcinogens in the Lake Ontario system is one of the goals of the project being undertaken by Dr. Hayes. It is known that fish feeding on the bottom of some industrially polluted regions in the Great Lakes have a higher than normal incidence of liver and skin tumours. The research team examined white suckers from the Hamilton Harbour region of Lake Ontario for preneoplastic changes that might indicate early exposure to chemical carcinogens. These studies indicate that white suckers and related fish such as brown bullheads are relatively resistant to carcinogens such as polycylcic aromatic hydrocarbons (PAHs) because their glutathione S-transferase (GST) enzymes can detoxify many mutagenic carcinogens. This resistance probably enables these fish to survive in noxious environments and get very few neoplasms in spite of chronic exposure to high levels of environmental carcinogens.

The researchers have also found that the liver neoplasms in white suckers have lost all of the protective GST enzymes present in a normal liver. This means that the preneoplastic cells become more sensitive to chemical-induced genetic alterations required for cancer development. These findings imply that the way chemicals cause cancer in sensitive inbred laboratory rodents is quite different and not predictive of how chemicals cause cancer in resistant species like these fish. They also demonstrate the need to know if humans have the enzyme systems that would make them resistant to PAHs and other potentially carcinogenic environmental pollutants. The methods developed in these studies are now being used to address this question.

Funding:

The WTF approved a grant of $74,040 for the project, with $34,290 payable in 1985/86 and $41,750 payable in 1986/87.

Matching Funds:

Matching funds for the project have been secured from the Ontario Ministry of the Environment, the Ontario Ministry of Agriculture and Food and Fisheries and Oceans Canada.

13. "Environmental Toxicology of the Welland River Wetland Area"

Co-ordinator:

Dr. Michael Dickman
Dept. of Biological Sciences
Brock University

Description:

Under the leadership of Dr. Dickman, the research team is examining the effects of industrial pollutants on selected species of the aquatic ecosystem in the Welland River wetland area.

To date, the project has a number of achievements to its credit. Included are: 1) the completion of vegetation maps of higher aquatic plant distributions in a wetlands area; 2) the preparation of site specific higher aquatic plant distribution maps below the major industries discharging shock loads into the Welland River; 3) Ames and SOS Chromotesting of the mutagenic nature of waste water and sediments near municipal and industrial point sources in the lower Welland River; 4) chemical analyses of the water and sediments for each of the municipal and industrial point sources in the lower Welland River; 5) development of a shock load data logger and water sampler for the study of the Welland River discharge point sources; 6) acute and chronic toxicity fish studies.

Funding:

The WTF approved a grant of $149,000, with $39,000 payable in 1985/86 and $55,000 payable in each of the second and third years.

Matching Funds:

The project has received matching funds from Employment and Immigration Canada, Fisheries and Oceans Canada and Ontario's Ministry of the Environment.

14. "Biomonitoring of Chlorinated Hydrocarbons in the Huron-Erie Corridor"

Co-ordinator:

Dr. Paul Hebert,
Great Lakes Institute
University of Windsor

Description:

Studies have shown that industries along the St. Clair River discharge a distinctive array of chlorinated hydrocarbons. The point source discharge of compounds such as octachlorostyrene provides an opportunity for gaining an understanding of the dispersion of organic contaminants in aquatic ecosystems. Prior work has made it clear that chemicals can often be detected more effectively by the use of biomonitors rather than direct water measurements.

Through the project, concentrations of selected organic contaminants have been determined in more than one thousand samples of organisms from the Lake St. Clair system. For mussels, chemical and site specific contaminant uptake patterns have been detected. A significant decrease in 1987 octachlorostyrene levels as compared to those in 1986 may reflect a decrease in the discharge of the contaminant. Preliminary analyses show that three fish species accumulate significant amounts of toxic compounds and show differences in contaminant levels between sites. Further, the evidence of higher hexachlorobenzene and octachlorostyrene levels in resident duck populations on Walpole Island than in migratory populations indicates that the ecosystem continues to be exposed to loadings of these organic contaminants.

Funding:

The WTF approved a grant of $150,000, with $49,000 payable in 1985/86, $52,000 payable in 1986/87 and $49,000 payable in 1987/88.

Matching Funds:

Matching funds for the project have been secured from Ontario's Ministry of the Environment.

15. "The Mortality of Amphibians in Sudbury Ponds"

Co-ordinator:

Dr. D.G. McDonald
Dept. of Biology
McMaster University

Description:

The toxic nature of surface waters low in pH and their resulting influence on the distribution and abundance of aquatic organisms is well recognized. Amphibians which breed in temporary forest ponds may be the group of aquatic organisms most vulnerable to acidic precipitation.

With support from the WTF, Dr. McDonald and Dr. Josef Freda have investigated the toxicity of acidic temporary ponds to amphibian embryos and larvae downwind of the copper smelter in Sudbury, Ontario. A comparison between laboratory tests and information from field surveys showed that: 1) aluminum and copper were not toxic to amphibians in ponds containing even low levels of dissolved organic compounds and 2) organic compounds are toxic to amphibians in low pH, dark water ponds. Mortality in the tadpoles of the Wood Frog, the American Toad and the Spotted Salamander were directly attributable to high concentrations of dissolved organic compounds in acidic ponds.

Funding:

The WTF approved a grant of $4,500 for this project.

Matching Funds:

Ontario's Ministry of Natural Resources provided the matching funds for the project.

16. "The Pharmacological Effects and Ecological Implications of Malathion Induced Cholinesterase Inhibition Determined From Field and Laboratory Studies"

Co-ordinator:

Dr. F.J. Ward
Dept. of Zoology
University of Manitoba

Description:

Organophosphorous and carbamate insecticides are widely used in western Canada for control of pests in agriculture and forestry. In this project, malathion exposed juvenile walleye experienced acetyl-cholinesterase inhibitions that are dose and age dependent. In the laboratory, walleye with low levels of enzyme inhibition exhibit energetically expensive and unsuccessful behaviours. Although these exposed walleye consume more calories, they are unsuccessful at capturing and handling their preferred prey size. The laboratory results are reflected at the ecological level in terms of growth. The field exposed group of walleye exhibit altered feeding patterns and a short-lived decrement compared to the control group. As the sham-treated group exhibits a similar response, the low level of enzyme inhibition induced may not be entirely responsible for the observed ecological effect.

Funding:

The WTF approved a grant of $43,524, with $21,762 payable in 1985/1986 and $21,762 payable in 1986/87.

Matching Funds:

The matching funds for the project were secured from Fisheries and Oceans Canada and the University of Manitoba.

17. "Cadmium Burdens in Deer Browse, Pellets and Soil From the Loring Deer Yard and Manitoulin Island"

Co-ordinator:

Dr. Glenn Parker
Dept. of Biology
Laurentian University

Description:

Dr. Glenn Parker is comparing environmental cadmium burdens in deer yards from two distinct geographical areas --- Port Loring, a "non-buffered" area subject to mineral enrichment through acidification, and Manitoulin Island, a stable "buffered" area.

Results from the project indicate: 1) increased cadmium burdens in the acidified soils of non-buffered sites; 2) high cadmium levels in 8 of the 12 forage species; 3) cadmium levels in trembling aspen reflected those levels found in the soil, thereby qualifying the forage species as a reliable bioindicator of prevailing cadmium burdens in yards subject to acid precipitation; 4) fecal pellets collected in geochemically sensitive areas were found to have higher cadmium content than those from buffered sites, thus reflecting a higher level of dietary exposure.

Funding:

The WTF approved a grant of $9,000 for this project.

Matching Funds:

Matching funds for the project have been secured from Ontario's Ministry of Natural Resources.

18. "The Effects of Deltamethrin on Prairie Ponds and Duck Populations"

Co-ordinator:

Dr. B.R. Neal
Dept. of Biology
University of Saskatchewan

Description:

The insecticide deltamethrin is known to dramatically reduce the invertebrate population in ponds for a few weeks after spraying. Therefore, it is suspected that it may reduce growth and survival of those ducklings which rely on invertebrates as a major food resource, particularly if the insecticide is used during the hatching season. By means of a field experiment, Dr. Neal is investigating the impact of deltamethrin on pond invertebrates and Mallard ducklings.

The 1987 results were disappointing. Populations of chironomid larvae, the most significant food for young mallards, declined after the spray period in both treatment and control ponds. While there was slightly more decline in the treated pond, there was little difference by the latter part of the season. However, some of the larger invertebrates in the water column were affected by the spraying. In addition, the growth and survival of ducklings in control and treatment ponds were uniformly poor.

Funding:

The WTF approved a grant of $87,075 for this project, with $40,000 payable in the first year, $22,000 payable in the second year and $25,075 payable in the third year.

Matching Funds:

Matching funds have been secured from NSERC, the University of Saskatchewan and Hoechst Canada Ltd.

19. "Fate of Carbofuran in Prairie Ponds and Its Effects on Aquatic Invertebrates"

Co-ordinator:

Dr. D.A. Boag
Dept. of Zoology
University of Alberta

Description:

In recent years, the extensive use of carbofuran in prairie agriculture, particularly for grasshopper control, has created a potential for contamination of small prairie wetlands through aerial applications. This study is seeking to determine the immediate, as well as the seasonal effects of carbofuran on those pond invertebrates which are an important component in the diet of growing ducklings. Four ponds were sprayed with carbofuran and the results indicated immediate reductions of the amphipod Hyallela azteca and trichopteran larvae at both shallow and deep sites. Other taxa, including midge larvae and damselfly nymphs, were apparently unaffected. The rapid disintegration of carbofuran in alkaline ponds is suggested as one factor minimizing the impact of the pesticide on all but the most sensitive taxa.

Funding:

The WTF approved a grant of $10,600 for the project. The entire sum was paid in 1985/86.

Matching Funds:

The matching funds were secured from the Delta Waterfowl and Wetlands Research Station, NSERC and the University of Alberta.

20. "Monitoring of Heavy Metal Exposure in Moose and Other Wildlife Populations in Ontario"

Co-ordinator:

Dr. M.G. Cherian
Dept. of Pathology
University of Western Ontario

Description:

Exposure to toxic chemicals such as cadmium is an increasing environmental hazard to wildlife in Canada, because of increased mining activities, increased used of Cd-Ni batteries, sewage sludge and phosphate fertilizers and other industrial uses of metals. In addition, acid precipitation increases the leaching of metals to the environment.

The study is measuring metal levels (CD and Zn) in moose livers and kidneys, as well as a specific metal binding protein, metallothionein (MT), in order to develop better indicators of metal toxicity and also to monitor environmental metal exposure levels in wildlife. Results to date include: 1) an age dependent increase in cadmium and metallothionein accumulation in moose liver and kidney; 2) evidence that accumulation of cadmium in kidney is increased three-fold in areas of high acid precipitation; 3) a direct positive correlation between cadmium and MT levels in moose kidney while a similar positive relationship existed between zinc and MT levels in liver samples. The results suggest that estimation of MT in kidney may be another useful biological indicator to monitor excessive environmental exposure to cadmium in a moose population.

Funding:

The WTF approved a grant of $46,200 for the research, payable in three annual instalments of $15,400 each.

Matching Funds:

The Medical Research Council and the Ontario Ministry of Natural Resources provided matching funds for the project.

21. "Development of Models Describing the Dynamic of Toxic Organic Chemicals in the Environment and Wildlife of the Great Lakes Basin"

Co-ordinator:

Dr. Don Mackay
Institute for Environmental Studies
University of Toronto

Description:

The project is seeking to develop a better understanding of the processes involved when toxic organic chemicals (such as PCBs) migrate through the abiotic environment and eventually move through food chains to wildlife. The focus is on the Great Lakes Basin and with the uptake of organochlorine compounds through various trophic levels of fish to gulls and gulls to eggs. This understanding is translated into a process model (e.g. of fish bioaccumulation) and ultimately into overall models for tracking contaminants from source to wildlife.

This modelling capability should help to protect wildlife from excessive contamination by closely and quantitatively linking source to target and by enabling wildlife to be used as biomonitors of the general state of contamination. Validation of the model is now underway. The model will be used to separately track accumulation of organochlorines by Herring Gulls from home and wintering lakes for a series of winter movement scenarios based on banding data. Thus, the percentage of contaminants coming from home and wintering lakes eggs and whole-body lipids can be related to plasma clearance rate or whole body half-life.

Funding:

The WTF approved a grant of $140,000 for the project, with $48,000 payable in 1985/86 and $92,000 payable in 1986/87.

Matching Funds:

Matching funds for the project have been secured from NSERC, the the Ontario Ministry of the Environment and the Petroleum Association for the Conservation of the Environment.

22. "Toxins in Rocky Mountain Forage Legumes: A Preliminary Assessment"

Co-ordinator:

Dr. M.A.M. Bell
Dept. of Biology
University of Victoria

Description:

There is growing concern over the role that selenium and other toxic compounds may play in influencing Elk, Big Horn Sheep, and Mountain Goat populations in the unique wildlife areas of the southern Rockies of British Columbia.

In this project, Dr. Bell is studying eight native legume species to determine levels of selenium accumulation, presence of alkaloid compounds and presence of misertoxin related compounds. The results will help identify those plants which are less toxic to ungulate species and thereby preferable for use in mine reclamation projects.

To date, tests for phenolic and terpenoid compounds have proved negative, as have tests for alkaloids. Nitro-toxins were detected in one species, A. robbinsii. Selenium analyses have not yet been completed.

Funding:

The WTF approved a grant of $9,024, with $4,264 payable in 1985/86 and $4,760 payable in 1986/87.

Matching Funds:

Matching funds for the project have been secured from the B.C. Science Council, Byron Creek Collieries and Line Creek Crowsnest Resources.

23. "Exposure Indicators for Metals Discharged by a Smelter"

Co-ordinator:

Dr. J.F. Klaverkamp
Dept. of Zoology
University of Manitoba

Description:

Eight lakes near the heavy metal smelter at Flin Flon, Manitoba were studied to determine effects of atmospheric metal deposition on aquatic organisms. Levels of copper, zinc and cadmium were measured in sediment, crayfish, and zooplankton. Sediment metal concentrations indicate that the four lakes nearest the smelter are highly contaminated, while the four lakes distant from the smelter are moderately contaminated by metals. Tissue concentrations of Cu, Zn, and Cd are generally elevated in organisms from lakes near the smelter. Metal-binding proteins (metallothioneins) were evaluated as sensitive biochemical indicators of metal exposure, and are highly correlated with tissue metal concentrations in the highly contaminated lakes only. Other physiological indicators of stress in fish indicate that fish are presently able to tolerate the degree of metal exposure found in all study lakes and that one biochemical response of fish to metal exposure is metallothionein production. The present results indicate that acclimation to metal exposure has occurred in organisms from the study lakes. However, the potential for long-term detrimental effects of atmospheric metal deposition on these lakes should not be discounted.

Funding:

The WTF approved a grant of $42,100 with $23,000 payable in 1986/87 and $18,900 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from Fisheries and Oceans Canada.

24. "Cadmium Burden and Its Effects on Birds"

Co-ordinator:

Dr. Rosemary Johnson
Dept. of Biology
Trent University

Description:

Increased levels of certain metals in lakes of the Canadian Shield have been attributed to both atmospheric deposition and the metal mobilization induced by acid rain. Currently, little information exists on the biological effects of these metals on secondary carnivores, such as insectivorous waterfowl.

Using laboratory and field techniques, Dr. Johnson is examining the distribution of cadmium in the body tissues of birds and its effects on individual and reproductive viability. In addition, Dr. Johnson is developing a non-fatal sampling technique for measuring toxic burden in waterfowl. The effectiveness of feathers in reflecting levels of cadmium in waterfowl is being assessed.

Results show that cadmium concentrations in the goldeneye feathers were much higher than those found in other studies of avian species. Differences between species in cadmium levels may be due to physiological differences, feather type, differences in molt, variable exposure rates and differences due to endogenous vs. exogenous contamination.

Examination of cadmium concentrations in the internal tissues of Goldeneye revealed 50.3 ppb for adult females and 53.1 ppb for adult males. This level is relatively low and it is unlikely that predators eating the tissue are at risk. Nor is the cadmium likely affecting the muscle metabolism. A population of laboratory Quail which had been exposed to food containing 7 ppm of cadmium revealed cadmium levels of 4242.7 ppb in liver tissues and 7415.4 ppb in kidney tissues.

Funding:

The WTF approved a grant of $23,350 with $11,697 payable in 1986/87 and $11,653 payable in 1987/88.

Matching Funds:

Matching funds have been received from Ontario's Ministry of Natural Resources and from Trent University.

25. "Toxicity of Chlorophenols to Zooplankton and Macrobenthos in Northern and Southern Ontario Lakes"

Co-ordinator:

Dr. K.R. Solomon
University of Guelph
Guelph, Ontario

Description:

Approximately 3.4 million kilograms of chlorinated phenols are used annually in Canada. Eighty percent of these are in the form of pentachlorophenol (PCP), which is used primarily as a wood preservative and in other activities associated with the forest industry. Tetrachlorophenols (TTCPs) stem from PCPs and are commonly found with them as contaminants in the environment. PCPs have been identified extensively throughout the Canadian environment.

The project is examining the fate and effects of PCP and TTCP in freshwater ecosystems typical of Canada. Laboratory studies showed that toxicity of technical and pure PCP was influenced by both exposure duration, age of organism and species of test organism. Other initial results include the fact that young Daphnia magna were equally susceptible to technical and pure PCP, whereas juveniles and adults were less tolerant of the pure PCP. Pure PCP was more toxic to juveniles at 48 and 72 hour exposure durations and more toxic to adults at all exposure durations.

Funding:

The WTF approved a grant of $57,000 with $30,000 payable in 1986/87 and $27,000 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from the federal Department of Supply and Services.

26. "Experimental Acidification of a Freshwater Wetland"

Co-ordinator:

Dr. Suzanne Bayley
Natural Resources Institute
University of Manitoba

Description:

While British wetlands have suffered massive destruction of vegetation in areas receiving high atmospheric deposition, the effects of acid rain on wetland ecosystems in North America are largely unknown.

To assess the effects of acid precipitation on the water chemistry, vegetation and insect fauna of a wetlands ecosystem, a small wetland in northwestern Ontario was experimentally acidified. Initial results include the following findings: 1) acid precipitation concentrations similar to the average values deposited in Eastern Canada stimulated growth of the Sphagnum vegetation; 2) some of the So4 applied in acid precipitation was reduced by the peat soil in the wetland, but retention within the wetland depended primarily on hydrological conditions; 3) emergence of Chironomidae from the wetland was not affected by acidification.

Funding:

The WTF approved a grant of $65,000 with $30,000 payable in 1986/1987 and $35,000 payable in 1987/1988.

Matching Funds:

The WTF contribution has been matched by funds from Fisheries and Oceans Canada.

27. "The Effects of Lakes Acidification on Avian Species"

Co-ordinator:

Dr. Jon C. Barlow
Dept. of Zoology
University of Toronto

Description:

The effects of acid rain on birds at the Experimental Lakes Area in northwestern Ontario is being assessed by Dr. Jon Barlow. The principal study animal is the Tree Swallow which nests in boxes around a number of experimentally acidified and unmanipulated control lakes in the area.

Reproductive success of Tree Swallows nesting around a lake with high acidity levels dropped from 75 percent in 1986 to 50 percent in 1988. This corresponded with a drop in pH from 5 in 1986 to 4.5 in 1988. Reproductive success is gauged by percent of eggs laid from which chicks hatch and the subset of them which subsequently fledge. Reproductive success of Tree Swallows breeding around control lakes averaged approximately 75 percent from 1986 to 1988. For Tree Swallows nesting around a lake, which had been allowed to recover from high acidity levels, reproductive success has increased from 0% in 1986 to 21% in 1987, and then to 78% in 1988.

Funding:

The WTF approved a grant of $19,634 for this project with $10,134 payable in 1986/87 and $9,500 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from the Natural Sciences and Engineering Research Council.

28. "Retinoid Monitoring for Dioxins and Related Compounds"

Co-ordinator:

Dr. Thomas Moon
Dept. of Biology
University of Ottawa

Description:

One of the problem areas associated with dioxin contamination of the Great Lakes is that wildlife is exposed to complex mixtures of a large number of compounds which are thought to have similar toxic action. These mixtures include certain PCPs, furans and other halogenated aromatic hydrocarbons as well as the dioxins themselves.

In laboratory experiments, Dr. Moon and his colleagues have found that a representative of this group of contaminants decreased the essential store of Vitamin A in birds. When Herring Gulls were studied at various locations on the Great Lakes, differences in various stores were again apparent and correlated with concentrations of dioxin in the gulls. Measuring Vitamin A stores, therefore, is an indicator of the effects of the dioxin-like compounds and may be used in environmental monitoring for dioxins.

The research team has also found that the ratio of two forms of Vitamin A in the egg yolk also correlates with the concentration of dioxin in Great Lakes gulls, and this is a second method useful in monitoring the biological effects of the dioxin-like contaminants. Currently, the research is focusing on the underlying mechanisms responsible for the dioxin-related changes in the vitamin A status of wild birds.

Funding:

The WTF approved a grant of $50,000 with $20,000 payable in 1986/87 and $30,000 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from the Natural Sciences and Engineering Research Council and Fisheries and Oceans Canada.

29. "Distribution of Radioactive and Chemical Pollutants in Soils, Plants and Game Animals in the Fire Controlled Ecosystems of Wood Buffalo National Park"

Co-ordinator:

Dr. Josef Svoboda
Dept. of Botany
University of Toronto

Description:

A two-season survey of radioactive and chemical fallout pollutants is being conducted in the fire-dominated ecosystems of Wood Buffalo National Park. The park straddles the boundary of Alberta and the Northwest Territories.

The objective of the research is to determine the burden of the fallout radionuclides and modern chemical pollutants in soils and biota of selected ecosystems in the Park; to find out whether these pollutants bioaccumulated in bison and moose; and to determine the effect of fire on these contaminants.

Preliminary results indicate that Wood Buffalo ecosystems have a persistent burden of the fallout fission product, Cesium - 137, in the moss and organic matter layers. This radio nuclide was deposited mainly during the era of atmospheric nuclear weapons testing which terminated in 1963. Further, the concentration of Cs-137 increases in moss and peat/ash layer in fire-affected stands. Fallout from the Chernobyl accident was also detected, representing about 13% of the total cesium in the organic layers. However, canopy foliage which normally showed only trace amounts of Cs-13 showed up to a 200% increase.

Funding:

The WTF approved a grant of $27,750 for the project with $13,500 payable in 1986/87 and $14,250 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from the Natural Sciences and Engineering Research Council, the Department of Indian and Northern Affairs and the Donner Canadian Foundation.

30. "Effects of Hexazinone Herbicide on Small Mammals Under Field Conditions"

Co-ordinator:

Mr. David Penner
McCourt Management Ltd.
Edmonton, Alberta

Description:

While the forestry herbicide hexazinone has been shown to have no major toxic impact and no significant bioaccumulation under laboratory conditions, field studies of the herbicide had not been carried out. As one component of a multi-disciplinary Forest Vegetation Management Project near Grande Prairie, Alberta, a series of small mammal investigations are being supported by the WTF.

The monitoring program is examining small mammal population characteristics, herbicide residues in animal tissues and habitat changes to assess uptake, persistence and possible consequences of the use of hexazinone herbicide on the food chain. Preliminary results do not show any acute toxicity effects based on animal abundance immediately before and within ten days of treatment with herbicide. Analytical results show low levels of hexazinone and one metabolite in the liver and kidney tissues in both composite samples from treatment plots.

Funding:

The WTF approved a grant of $55,000, with $30,000 payable in 1986/87 and $25,000 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from the Canada/Alberta Forest Resource Development Agreement and the Canadian Forestry Service.

31. "Effects of Grasshopper Insecticides Upon Valuable Wildlife"

Co-ordinator:

Dr. D.G. Irvine
Toxicology Research Centre
University of Saskatchewan

Description:

There is widespread concern over the possible toxic effects on non-target species of the insecticides used to control grasshoppers on the Canadian Prairies. There are two pathways by which such chemicals may enter the wildlife ecosystems: direct exposure and consumption of poisoned grasshoppers.

With support from a number of agencies, Dr. Irvine and his research team are assessing the impact of carbofuran on terrestrial prairie wildlife. Initial results include the finding that carbofuran affected the nervous system of several species of wildlife. Reductions in the functioning of the brain enzyme were from 45 to 60 percent, generally with recovery to normal levels in a very short time. During the second half of the project, mathematical models will be used to summarize the pathways to, and impacts of carbofuran on, selected wildlife. Efforts will be made to extrapolate the results to other wildlife species, and other insecticides.

Funding:

The WTF approved a grant of $82,245, with $42,995 payable in 1986/87 and $39,250 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from the Saskatchewan Natural History Society, the Saskatchewan Wildlife Federation, the Government of Saskatchewan and Agriculture Canada.

32. "Snapping Turtles as Biomonitors of Organochlorine Contamination in Wetlands"

Co-ordinator:

Dr. Ronald Brooks
Dept. of Zoology
University of Guelph

Description:

Snapping Turtles occur throughout eastern Canada in a variety of wetlands. A number of characteristics appear to make the species ideal for monitoring chemical contaminants, and the impact and movement of these substances through different trophic levels. Snapping Turtles accumulate high concentrations of organochlorine contaminants in both tissues and eggs. In addition, they have an omnivorous diet, great longevity and sedentary habits.

Under the guidance of Dr. Brooks, the project is assessing the value of the Snapping Turtle as a biomonitor of organochlorine contamination in aquatic ecosystems. Initial results show significant contamination of turtle eggs taken from a Hamilton Harbour site. Contaminant levels were also high in turtle tissues from the site. Turtle hatchlings from Hamilton Harbour and Cranberry Marsh on Lake Ontario also showed much greater incidences of deformities than hatchlings from Lake Erie and from Algonquin Park. Deformities included curled tails, missing tails, leg deformities and missing claws and eyes. Based on the project's results, the Canadian Wildlife Service is now exploring the use of Snapping Turtles as biomonitors of toxic contamination.

Funding:

The WTF approved a grant of $30,000 with $15,000 payable in 1986/87 and $15,000 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from Ontario's Ministry of Natural Resources.

33. "Impact of Airborne Chlorinated Hydrocarbons in Aquatic Ecosystems"

Co-ordinator:

Dr. D.J. McQueen
Dept. of Biology
York University

Description:

The work is focused on the recent discovery that freshwater flora and fauna, from lakes that have never received direct inputs of chlorinated hydrocarbons, contain surprisingly large quantities of these toxic substances. The hypothesis is that these toxic materials enter lakes in association with airborne particles and precipitation.

Initial results indicate measureable levels of PCBs, chlordane and DDE in a number of lakes in the Bancroft/Haliburton region of Ontario. One interesting finding has been the discovery of a high correlation between high nutrient levels in a lake and low levels of PCBs. This indicates that eutrophic systems are more protected from PCB contamination than non-eutrophic systems.

Funding:

The WTF approved a grant in the amount of $45,654 with the entire grant payable in 1986/87.

Matching Funds:

The WTF contribution has been matched by funds from the Natural Sciences and Engineering Research Council.

34. "Metal Sequestration in Marine Bivalves of the N.E. Pacific"

Co-ordinator:

Dr. R. Reid
Dept. of Biology
University of Victoria

Description:

A Mussel Watch program along the coast of the N.E. Pacific is studying the uptake of metals by a number of bivalves. Two mussel species --- Yoldia scissurata and Compsomyax subdiaphana are important in the diet of ground-fish, some diving birds and possibly grey whales. These are the focus of work at the University of Victoria.

To date, metal containing granules have been discovered in the Yoldia species. Through EDX analysis it was found that a specific granule type is present in all the tissues examined which are characterized by containing the elements Si, P, S, Ca, Cr, Fe, Ni and Cu. It was also discovered that the Yoldia species recycles old sediments to the interface and water column, as well as absorbing metals from the old sediments. The potential of this genus for prolonging the effects of dumping and tailing deposition will depend on local history and natural sedimentation rates.

Funding:

The WTF approved a grant of $29,989 with $15,076 payable in 1986/87 and $14,913 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from the Natural Sciences and Engineering Research Council.

35. **"Biological Monitoring for Airborne Organic and Metal Contaminants in the Upper Great Lakes Region of North America."**

Co-ordinator:

Dr. Pamela Stokes
Institute for Environmental Studies
University of Toronto

Description:

Lower plants, lacking cuticle and transport systems, acquire most of their nutrients from the atmosphere. Airborne contaminants also become adsorbed to or incorporated into the tissues of these plants as a result of wet and dry deposition.

The study is examining the potential of these plants as monitors of trace organics, as well as metals. Thirty-five sites in the Upper Great Lakes Basin have been targeted and metals, sulphur and trace organics (PCBs, PAHs and pesticides) in the lichens and mosses are being determined.

Preliminary results indicate that concentrations of trace organics in lichens in the Upper Great Lakes Basin are in most cases lower than elsewhere in the world. Concentrations of most species are fairly uniform across the study region, suggesting an absence of local sources and an influence of distant sources. Further, there is a suggestion for some contaminants of higher concentration levels in the southern portion of the Great Lakes basin, presumably a reflection of atmospheric transport and deposition from more heavily polluted areas.

Funding:

The WTF approved a grant of $30,000 for the project, with $15,000 payable in 1986/87 and $15,000 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from Ontario's Ministry of the Environment.

36. "Toxicology of Peregrine Falcons in the Keewatin District of the NWT"

Co-ordinator:

Dr. D.A. Boag
Dept. of Zoology
University of Alberta

Description:

In this project, eggshell thinning and organochlorine residues in egg contents, blood plasma of adults and young, and prey species, were determined for Peregrine Falcons nesting at Rankin Inlet, N.W.T. Eggshells from 88 eggs representing 65 clutches of 26 pairs from 1981-1985 average 14 % thinner than eggs collected prior to 1947; only 4 % below thinning levels considered critical for successful reproduction.

DDE residues averaged about 10ppm (wet weight) in 22 adled eggs, and about 1.1 ppm (wet weight) in 88 blood plasma samples from adults. DDE levels in the contents of eggs were negatively correlated with shell thickness. Levels of other organochlorine pesticides were often highly correlated in both plasma and egg samples, suggesting that peregrines are exposed to these compounds collectively. Only nine percent of all peregrine pairs to initiate a breeding attempt failed with egg breakages associated with pesticide contamination. Relatively low pesticide residues and high reproductive success of this population are explainable in that these birds use a low proportion of highly migratory prey species on the breeding grounds. As part of the project, the researchers are developing recommendations regarding the monitoring of pollution and population trends of tundra peregrines in the future.

Funding:

The WTF approved a grant of $20,150 payable in 1986/87.

Matching Funds:

The WTF contribution has been matched by funds from the Government of the NWT, the Boreal Institute for Northern Studies and Agriculture Canada.

37. "The Feeding Ecology of Herring Gulls"

Co-ordinator:

Dr. Erica Nol
Dept. of Biology
Trent University

Description:

The Herring Gull overwinters in the Great Lakes region and is, therefore, an important indicator species for the presence of organochlorine compounds in the Great Lakes ecosystem. The project is designed to elucidate the ecological basis of different levels of organochlorine compounds in male and female Herring Gulls.

The winter feeding ecology of the birds is being observed over two years. Detailed observations, using focal-animal sampling on colour-banded individuals of each sex, are being taken at various feeding areas. Individuals are being observed at sanitary land fill sites, in agricultural fields and along the Lake Ontario shoreline. Fecal and pellet samples are being collected and analyzed. Samples from the roost will provide general indications of the diet of the species in winter, whereas samples of the fresh feces of individuals of known sex will corroborate the data on sex-specific feeding patterns obtained from direct observations.

Funding:

The WTF has approved a grant of $1,062 in support of the project. The grant is payable in two instalments, with $625 payable in 1986/87 and $437 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from the Natural Sciences and Engineering Research Council and Trent University.

38. "A Proposal for the Study of Cadmium in Wildlife in Manitoba"

Co-ordinator:

Mr. Paul Paquet
Riding Mountain Biosphere Program
Riding Mountain National Park, Manitoba

Description:

Cadmium has been released into the environment at an accelerated rate during the twentieth century, particularly as a result of industrial activity. High concentrations of toxic heavy metal in humans have been associated with renal dysfunction and other physiological disorders. Recent studies have identified wild game as a potential source of cadmium for humans.

Preliminary results from 122 moose kidneys and livers suggest cadmium concentrations frequently exceed levels considered safe for regular consumption by humans (2 mg/kg). Six of the tests revealed levels in excess of 20 milligrams of cadmium per kilogram of tissue. All six animals that contained elevated levels were from the western portion of the province between the Flin Flon/ Snow Lake area and Riding Mountain National Park. Values recorded for kidneys were significantly higher than levels for liver tissues and there was a positive correlation between cadmium levels in livers and kidneys and increasing age of moose.

Funding:

The WTF approved a grant of $42,000 for the projects, with $21,000 payable in 1986/87 and $21,000 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from the Wildlife Branch of the Government of Manitoba.

39. "Novel Use of Stress-Induced Morphological Abnormalities in Lichens as an Early Warning of Forest Decline"

Co-ordinator:

Dr. Thomas C. Hutchinson
Institute for Environmental Studies
University of Toronto

Description:

In previous field experiments, sprays of simulated acid rain were made of selected boreal forest lichens in permanent field plots. Specific growth abnormalities including unusual branching pattern, changes in lipid content of the algal cells of the lichen and alterations in both morphology and anatomy occurred.

Through this project, Dr. Hutchinson is examining the morphology, anatomy and tissue chemistry of a variety of lichen species at sites in Quebec, Vermont and New York. Observations at these sites indicate a general unbalancing of the symbiosis that exists between the algal and fungal components of the lichen. Both air pollution and associated nutritional factors may lead to this response.

Funding:

The WTF approved a grant of $97,000 for the project, with $48,500 payable in 1986/87 and $48,500 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from the Canadian Forestry Service and the Natural Sciences and Engineering Research Council.

40. "Metal Contamination of Wetland Food Chains in the Bay of Quinte"

Co-ordinator:

Dr. Adele Crowder
Dept. of Biology
Queen's University

Description:

The Bay of Quinte in Lake Ontario is approximately 90 kilometres long and receives drainage from several large river systems. The Moira River carried contaminated sediment from mines into the Bay from 1880s to the 1960s resulting in contamination of deep water sediments by metals such as Ag, As, Cu, Hg, Ni and Pb. Hypertrophication occurred during the 1950s and 1960s; control of point sources of P lowered nutrient loading after 1970 but inshore water remains opaque. Macrophyte beds have lower diversity than inland marshes.

Results to date show several patterns of distribution of elements. The usefulness of species as bioassays differed. S. elodes accumulated significantly higher levels of Cu and V than H. trivolvis collected from the same sites. The macrophyte Myriophyllum spicatum L. acted as a bioaccumulator of Pb whereas Vallisneria americana at the same site did not.

Funding:

The WTF approved a grant of $42,593, with $21,550 payable in 1986/87 and $21,043 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from Ontario's Ministry of the Environment.

41. "Effect of Silvicultural and Glyphosate Spraying on Breeding Birds and Small Mammals"

Co-ordinator:

Dr. Bill Freedman
Dept. of Biology
Dalhousie University

Description:

Herbicides are increasingly being used in forestry to release conifer seedlings from competition with other vegetation. In Canada, an important herbicide is the organophosphate glyphosate called Roundup.

In this project, Dr. Freedman is testing the hypothesis that herbicide treatment causing a decline in the biomass and productivity of surrounding vegetation will also lead to a bird community of low abundance and species richness. Preliminary results indicate that only two moderately prominent species, Alder Flycatcher and Mourning Warbler, showed population decreases that appeared to be related to the herbicide treatment. However, these species continued to breed on the sprayed plot and there was no evidence of a decrease for other species. A post-breeding bird census indicated that there was a significantly higher density of birds on the unsprayed reference plot, compared with any of the five sprayed plots.

Funding:

The WTF approved a grant of $16,850 with $10,000 payable in 1986/87 and $6,850 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from Dalhousie University and from Nova Scotia's Department of Lands and Forests.

42. "In Situ Studies of the Effects and Persistence of Bromoxynil Octanoate in Prairie Wetlands

Co-ordinator:

Dr. Rodger D. Titman
Dept. of Renewable Resources
Macdonald College, McGill University

Description:

Each year, over 12 million hectares of cropland on the Canadian Prairies are treated with herbicides. Because of an intimate association between cropland and small wetland basins, it is inevitable that herbicides used in the prairie pothole region will find their way into non-target areas. The response of wetland ecosystems is difficult to predict because of complex interactions between individuals, species and trophic levels.

Under the guidance of Dr. Titman, the research team is studying the effects and persistence of the octanoic ester of the herbicide bromoxynil in a prairie wetland ecosystem. Initial results showed no indication of a large-scale die-off of naturally occurring fish or invertebrate populations in the ponds immediately following herbicide treatment. However, there appears to be some immediate effect of application on levels of caldocerans and metaphytic algae in ponds. The application of bromoxynil to the study ponds at a nominal rate of 100 and 500 ug/L resulted in complete death within 24 hours of caged stickleback fry.

Funding:

The WTF approved a grant of $23,056 in support of the project with $14,092 payable in 1986/87 and $8,964 payable in 1987/88.

Matching Funds:

The WTF contribution has been matched by funds from the Delta Waterfowl and Wetlands Research Station, McGill University, Fisheries and Oceans Canada and May & Baker Canada Ltd.

43. "The Impact of Forest Decline on Insectivorous Birds"

Co-ordinator:

Dr. Yves Mauffette
Dept. of Biological Sciences
University of Quebec at
Montreal

Description:

Atmospheric pollution has been cited as a major cause of forest dieback. Several toxic chemicals have been shown to directly affect individual trees or complete stands by reducing growth or in extreme cases causing mortality. Presently, maple dieback in Quebec has been reported to extend over an area of 24,000 square kilometres and is progressing at a yearly rate of five percent within the hardwood forests. The degradation of these forest ecosystems will have a direct impact on the fauna present in these systems.

With support from the WTF, Dr. Yves Mauffette is assessing biological changes of insect-eating bird species during their breeding season in declining maple forest. It is hypothesized that these degraded forests lead to losses of suitable habitats and a scarcity of food. The project is monitoring three selected bird species (Red-eyed Vireo, Least Flycatcher and Black-throated Blue Warbler) in healthy and declining forests and comparing behavioural changes occurring in response to environmental perturbations. For each species, density and foraging territory will be estimated; diet and feeding ecology will also be assessed.

Funding:

The WTF approved a grant of $40,000 for the project.

Matching Funds:

Le Conseil des Recherches et Services Agricoles du Quebec and Employment and Immigration Canada have provided the matching funds for the project.

44. "Effects of Dicofol on Kestrels"

Co-ordinator:

Dr. David Bird
Macdonald College
McGill University
Montreal, Quebec

Description:

The project involves an investigation of the eggshell thinning effects of dicofol pesticide and the potential of dicofol to cause developmental abnormalities in the American Kestrel, a species sensitive to the effects of DDE and closely related to the endangered Peregrine Falcon. The pesticide dicofol is one of the few organochlorine pesticides still in use in North America, and is a close structural analog of DDT and DDE. Dicofol is commonly used in cotton and citrus for the control of mites under the registered name of Kelthane, and is registered for use both in the United States and Canada.

Dr. David Bird, of McGill University, and Dr. Michael Fry, of the University of California are monitoring reproductive function in both first and second generation Kestrels. Initial results indicate that the presence of Kelthane, Dicofol and DDE in female Kestrels caused eggshell thinning, increased shell breakage, reduced fertility and reduced nest hatching success of exposed eggs. During 1988, the study will investigate the effects of dicofol and DDE on Kestrel embryos and determine the reproductive performance of birds hatched from contaminated eggs.

Funding:

A grant of $48,482 was approved.

Matching Funds:

Matching funds for the project have been received from NSERC and the University of California.

45. "Effect of Fenitrothion on Zebra Finches"

Co-ordinator:

Dr. Peter Boag
Dept. of Biology
Queen's University

Description:

The aerial spraying program to control spruce budworm in eastern Canada and the northeastern United States has been one of the longest running and largest programs of its kind in the world. Aerial spraying has also been used to control hemlock looper in Newfoundland, the spruce budmoth in New Brunswick and the Gypsy Moth in Ontario and Quebec. Assessing the impact of this forest spraying on forest songbirds involves a combination of field monitoring and laboratory techniques: Ld50 trials with domestic species, field observations (including singing male surveys and mortality counts) and songbird brain cholinesterase (ChE) measurements). The first two are regarded as fairly crude methods of assessing the likelihood of songbird mortality, while the ChE method is regarded as a more sensitive measure.

In this project, Dr. Peter Boag is investigating the sublethal effects of ChE inhibiting insecticides on the behaviour and reproduction of Zebra Finches. It is expected that the behavioural assay developed in this study will be useful in screening new forestry insecticides for their potential impact on forest songbirds, bridging the existing gap between traditional laboratory LD50 trials and small-scale field trials.

Funding:

A grant of $22,650 has been approved.

Matching Funds:

Matching funds for the project have been received from the Canadian Forestry Service and NSERC.

46. "Mercury Pathways: The Role of Benthic Invertebrates"

Co-ordinator:

Dr. Pamela Stokes
Institute for Environmental Studies
University of Toronto
Toronto, Ontario

Description:

High mercury concentrations in fish have been found in different situations such as in rivers and lakes which received discharges from mercury contaminated effluents, in flooded lakes and hydroelectric reservoirs, and even in lakes remote from any identified source of mercury. This fish mercury represents a risk to consumers, including man and is passed on to fish eating birds and mammals.

The study's aim is to achieve a better understanding of mercury pathways in aquatic ecosystems which have no apparent discharges of mercury. Specifically, it will investigate the role of invertebrates in mercury cycling. A number of lakes will be surveyed to determine levels of mercury in several groups of invertebrates (crayfish, mussels, insects, gastropods, etc.) to assess the contribution of benthos to fish and wildlife mercury. The project should be able to identify a good biomonitor for mercury and fill in the missing link that has existed between sediment mercury and mercury in higher trophic levels (fish, birds and mammals).

Funding:

The WTF approved a grant of $22,416 for this project.

Matching Funds:

Matching funds have been secured from the Ontario Ministry of Natural Resources and the Ontario Ministry of the Environment.

47. "Dynamics of Organic Contaminants Uptake By Natural Seston"

Co-ordinator:

Dr. Henry Peters
Dept. of Biology
McGill University
Montreal, Quebec

Description:

In the laboratory, uptake rates and bioconcentration factors of organic chemicals by algal cultures can be predicted from physico-chemical characteristics of the chemical. Dr. Peters is testing, and possibly extending, this model for use in natural plankton communities.

Water samples collected from seven lakes in the Eastern Townships and lower Laurentians will be contaminated with radioactively labelled organic contaminants and the uptake of the xenobiotics by seston will be followed over time. The data will be analysed to yield estimates of the instantaneous rate of uptake and asymptotic bioconcentration. Linear regression will relate these two measures of biological activity to physico-chemical properties of the contaminants and whole lake properties such as biomass, pH, and dissolved organic material.

Funding:

The WTF approved a grant of $15,460

Matching Funds:

Matching funds have been received from NSERC.

48. "Contaminants and Population Trends in Razorbill Auks"

Co-ordinator:

Dr. J.H. Bedard
Biology Dept.
Laval University
Quebec City, Quebec

Description:

An overall pattern of declining contaminants loads in seabirds has been reported recently for most Canadian coastal areas with the exception of the St. Lawrence estuary. This region has been known for quite sometime as a particularly polluted one and the situation has been alarming for fish and marine mammals. Most scientists feel, however, that environmental contaminants have not affected the productivity of marine birds in this area.

One key fish-eating seabird, the Razorbill Auk, has exhibited contradictory population changes with a steady decrease in the St. Lawrence Gulf between 1965 and 1980. Since then, numbers have rebounded. This is despite the fact that environmental contaminants have not decreased in the area.

In cooperation with the Canadian Wildlife Service, Dr. Bedard is surveying contaminant levels in Razorbill Auks in both the St. Lawrence Estuary and Gulf in order to contrast contaminant loads and productivity on the one hand and demographic trends on the other. A correlation between high contaminant loads and high productivity might indicate that other factors, such as poaching, are governing the abundance of the Razor-Bill Auk.

Funding:

The WTF approved a grant of $10,650 for this project.

Matching Funds:

Matching funds have been secured from NSERC and La Societe Duvetnor Ltee.

49. "Effects of Hexazinone Herbicide on Small Mammal Populations Under Field Conditions"

Co-ordinator:

Mr. David Penner
Penner and Associates Ltd.
Sherwood Park, Alberta

Description:

The WTF is supporting the second phase of a study on the effects of a forest herbicide on small mammal populations. Details on the first phase are outlined under Project #30.

During the second phase, small mammal populations will be monitored by live-trapping techniques on paired plots of both herbicide treated and control blocks. The collection of small mammal specimens for the analysis of kidney and liver tissues for herbicide residues will also be performed.

The results expected from population monitoring include a reliable estimate of small mammal abundance, species composition, survival of resident animals, reproductive characteristics and behaviour on both the herbicide treated and control areas before treatment. Investigations of hexazinone residues in small mammal tissues will document herbicide uptake and persistence and possible consequences of the use of herbicide in the food chain. The results will be linked to habitat changes and herbicide residues from forage and plant tissue analysis being carried out in order to assess effects of hexazinone herbicide use on small mammal populations in the field. These results will be assessed for implications on other wildlife species.

Funding:

The WTF approved a grant of $25,000 for 1987/88.

Matching Funds:

Matching funds have been received from the Canada/Alberta Forest Resource Development Agreement and the Canadian Forestry Service.

50. "Toxicology of Carbofuran in Mallard Ducklings"

Co-ordinator:

Dr. K.R. Solomon
University of Guelph
Guelph, Ontario

Description:

Pesticide use in the pot-hole region of the Prairies presents a special problem. Agricultural fields are closely interspersed with small productive wetlands, or sloughs, and contamination of these ponds is inevitable either through field runoff, drift or direct exposure through overhead aerial spraying. Prairie sloughs and their surrounding upland regions provide habitat for a wide variety of mammalian and avian organisms, but are perhaps most notable for their proliferation of waterfowl, the Canadian prairies producing about 26 percent of North America's total breeding duck population.

Through this project, Dr. Solomon is addressing the impact of carbofuran spraying on mallard ducklings. The objectives of the study are to: 1) determine the accumulation of carbofuran in aquatic invertebrates exposed to the chemical; 2) determine if contaminated invertebrates are important in causing duckling mortality or obvious behavioural changes, through carbofuran poisoning; 3) examine the metabolism of dietary carbofuran in ducklings. The excretion pathways and role of metabolism will be monitored in ducklings exposed to sublethal doses of carbofuran.

Funding:

The WTF approved a grant of $7,222 for this project.

Matching Funds:

Matching funds have been secured from the Delta Waterfowl and Wetland Research Station.

51. "The Impact of Strychnine on Burrowing Owls"

Co-ordinator:

Dr. Paul James
Saskatchewan Museum of Natural History
Regina, Saskatchewan

Description:

Strychnine has a long history of impact on wild birds, particularly birds of prey. Despite this, it is the rodenticide still most commonly used to control Ground Squirrels in Saskatchewan. Because the threatened Burrowing Owl nests in close association with Ground Squirrels, the bird has the potential to be adversely affected by this agricultural practice.

With support from the WTF, Dr. James is determining whether the use of strychnine to poison Ground Squirrels is detrimental to breeding Burrowing Owls. (Previous research by Dr. James has documented a significant decline in the breeding success of Burrowing Owls exposed to the insecticide carbofuran.) The research will evaluate the risk to Burrowing Owls by comparing the survival and breeding performance of owls in pastures where farmers use strychnine for ground squirrel control with those of owls from pastures where strychnine is not used.

Funding:

The WTF approved a grant of $5,000 for this project.

Matching Funds:

Matching funds were secured from Saskatchewan's Museum of Natural History.

52. "Toxicology and Pathology of St. Lawrence Marine Mammals"

Co-ordinator:

Dr. Pierre Beland
St. Lawrence National Institute
of Ecotoxicology
Rimouski, Quebec

Description:

Since 1982-1983, a network of individuals around the St. Lawrence has produced each year reports of some forty dead marine mammals belonging to ten species. Chemical analyses and necropsies on Beluga Whales have evidenced very high organochlorine levels and an unusual incidence of severe lesions, highlighting the hypothesis that contaminants are responsible for the failure of this population to recover over the last 25 years. Sampling of several individuals of other species has shown variable contaminant levels, with grey seals and harbour porpoises having particularly high levels.

Through this project, Dr. Beland is extending chemical analyses of tissues and necropsies to all species reported through 1988-1990. It is expected that sufficient numbers of Belugas will be collected to fully document the contamination of this species. The project will provide an inter-species comparison and the long-term approach of the work will provide the necessary data base for assessing trends in toxic chemicals at the top of St. Lawrence food webs. Finally, the program will provide a first evaluation of contamination by polycyclic aromatic hydrocarbons (PAHs) in St. Lawrence marine mammals.

Funding:

The WTF approved a grant of $75,000 in support of this project.

Matching Funds:

Matching funds have been received from Alcan Ltd., and Fisheries and Oceans Canada.

53. "Radiation Levels in the Cape Churchill Caribou"

Co-ordinator:

Ms. Barbara Draper
Institute of Arctic Physiology
Churchill, Manitoba

Description:

The research project was developed in response to the Chernobyl nuclear disaster. Ms. Draper is seeking to determine the levels of radioactive materials in the caribou of the Churchill, Manitoba area. The caribou has been chosen as it is hunted in this area and also the movement of radioactive materials through this particular food chain is significant.

Lichens, a slow growing source of caribou nutrient, are particularly adept at trapping and retaining nuclear fallout material. The elements 137 Cs and 90 Sr (being the most critical elements of nuclear fallout) in the lichens are then ingested by caribou, where they are distributed throughout the body.

Ms. Draper is colleting samples of caribou meat from local hunters. These samples are from the non-migratory Cape Churchill herd and are being sent to Health and Welfare Canada where they will be analyzed by the Hazards Division. The WTF is providing assistance for the collection and transportation of the samples.

Funding:

The WTF approved a grant of $300 in support of this project.

Matching Funds:

Matching funds have been received from Health and Welfare Canada